PROCEEDINGS

OF THE

NATIONAL ACADEMY OF SCIENCES

INDIA

1955

VOLUME 24 SECTION—A PART IV

PROCEEDINGS

OF

THE SYMPOSIUM

ON

RECENT TRENDS IN SOIL RESEARCH

PART IV

ALLAHABAD

PUBLISHED BY THE COUNCIL

Price Rs. 20 (India) $ 5.00 (Foreign)

PROCEEDINGS

OF

THE SYMPOSIUM

ON

RECENT TRENDS IN SOIL RESEARCH

HELD DURING

THE TWENTY-FOURTH ANNUAL SESSION

OF

THE NATIONAL ACADEMY OF SCIENCES, INDIA

AT

THE UNIVERSITY OF SAUGAR, SAUGAR (M. P.)

ON

27th & 28th DECEMBER 1954

PART IV

CONTENTS

SECTION—4

SOIL FERTILITY

PROCEEDINGS
OF THE
NATIONAL ACADEMY OF SCIENCES INDIA
1955

VOLUME 24 SECTION—A PART IV

SECTION—4

EFFECT OF CONTINUOUS APPLICATION OF AMMONIUM SULPHATE ON PADDY AND SOIL IN WEST BENGAL

By

S. DIGAR *and* A. K. MANDAL*

Department of Agriculture, West Bengal

Communicated by Dr. S. K. Mukherjee

(*Received on 18th October, 1954*)

In the drive for increasing food production, the role of ammonium sulphate as the most easily controllable source of nitrogen is very important. Inspite of the prejudice held by many against it, the consumption and the production of this fertilizer in our country is steadily mounting up. In our Second Five-year Plan a clamour for setting up of more than one factory in India by different States is a sufficient proof that be, whatever the prejudice against it, ammonium sulphate, will surely take a very important place in our programme of increasing food production.

The antagonists of ammonium sulphate hold the opinion that the,—

(*i*) Repeated application of ammonium sulphate will decrease crop yield.

(*ii*) It will spoil the soil.

(*iii*) More rational antagonists have suggested, that this should be used with phosphatic manure, or along with farmyard manure and a programme of liming must be followed.

This article very briefly gives the average effect of continuous application of ammonium sulphate on crop and the soil, over a period of six years.

The experiments were started from 1948-49. Six manurial experiments were laid down, two experiments in each of the three farms at Chinsura, Suri and Behrampore. They had the following treatments :—

EXPERIMENT I — N @ 0, 30, 60, 90 and 120 lbs/acre as amm. sulph., P_2O_5 @ 0, 20 and 40 lbs/acre as bonemeal, FYM. @ 0 and 100 mds/acre in all combinations.

*Work financed jointly by the I. C. A. R. and the West Bengal Govt.

EXPERIMENT II :—N @ 0, 30, 60, 90 and 120 lbs/acre as amm. sulph., P_2O_5 @ 0, 20 and 40 lbs/acre as bonemeal, lime @ 0, 4 and 8 cwt/acre in all combinations.

The details of the experiments are as follows :—

Farm	Date of starting	Crop and variety	Design of the experiment	Number of replication
Chinsura	Expt. 1 1948-49	Aman paddy-Jhingasail	Split plot	6
	Expt. 2 1948-49	,, ,, ,,	,,	6
Suri	Expt. 1 1948-49	Aman paddy-Bhasamanik	Partially confounded	4
	Expt. 2 1948-49	,, ,, ,,	,,	2
Berhampore	Expt. 1 1949-50	Aus paddy-Dharial	Split plot	4
	Expt. 2 1949-50	,, ,, ,,	,,	4

The summary of the grain and straw yield due to these treatments are given in the Tables I and II.

TABLE I

Showing the average yield of grain and straw, obtained from these experiments in maunds per acre

EXPERIMENT I

(Treatment per acre basis)

Farm and No. of years		No manure	30 lbs N	60 lbs N	90 lbs N	120 lbs N	20 lbs P_2O_5	40 lbs P_2O_5	100 mds F Y M.
Chinsura Farm (average of 5 years)	Grain	18·68	21·19	19·84	18·12	17·91	19·62	21·17	20·57
	Straw	35·23	40·62	42·84	44·12	47·11	36·16	36·90	37·73
Suri farm (average of 6 years)	Grain	25·36	33·17	34·16	—		28·40	26·60	29·42
	Straw	39·20	54·05	58·49	—		42·81	39·73	45·85
Berhampore farm (average of 5 years) (aus paddy)	Grain	8·03	10·51	13·02	13·90	12·36	7·83	7·10	8·05
	Straw	14·28	18·49	22·28	24·45	25·16	14·22	13·36	15·97

EXPERIMENT II

(Treatment per acre basis)

Farm and No. of years		No manure	30 lbs N	60 lbs N	90 lbs N	120 lbs N	20 lbs P_2O_5	40 lbs P_2O_5	4 cwt lime	8 cwt lime
Chinsura farm (average of 5 years)	Grain	18·07	21·24	20·14	18·74	16·80	19·39	19·17	18·41	18·01
	Straw	34·73	40·23	44·86	45·76	45·87	37·62	39·14	32·59	36·07
Suri farm (average of 6 years)	Grain	19·03	30·54	34·06	30·33	—	26·52	28·00	24·92	26·07
	Straw	32·40	50·86	59·60	58·40	—	43·84	41·18	39·85	39·87
Berhampore farm (average of 5 years) (aus paddy)	Grain	8·98	13·36	16·95	14·73	—	8·66	8·97	7·96	7·86
	Straw	19·48	26·52	29·33	30·38	—	18·72	17·78	15·61	16·90

TABLE II

Showing the effect on chemical composition of the soils from the plots collected during 1954

(on oven-dry basis) (depth of soil 0″—6″)

Experiment I

Farm and No. of years	Items of analysis	(Treatments per acre basis) No manure	30 lbs N	60 lbs N	90 lbs N	120 lbs N	20 lbs P_2O_5	40 lbs P_2O_5	100 mds FYM
Chinsura farm 6 years	Organic Carbon %	1·006	1·0311	1·1130	1·0710	1·0216	0·9660	0·9461	1·0699
	Bases solb. in 0·5 N acetic acid (m. e. %)	22·47	23·52	22·05	22·47	23·73	23·94	23·52	22·60
	Calcium solb. in 0·5 N acetic acid (m. e. %)	17·05	17·64	17·05	16·80	17·47	17·68	18·06	17·22
	pH	6·6	6·6	6·5	6·4	6·5	6·4	6·4	6·3
Suri farm 6 years	Organic Carbon %	0·3495	0·2990	0·2838	—	—	0·3160	0·3050	0·3091
	Bases solb. in 0·5 N acetic acid (m. e. %)	4·05	5·25	5·05	—	—	5·25	5·45	4·12
	Calcium solb. in 0·5 N acetic acid (m. e. %)	3·56	4·61	4·21	—	—	4·61	5·04	3·56
	pH	5·6	5·7	5·5	—	—	5·8	5·7	5·5
Berhampore farm 5 years	Organic Carbon %	0·5727	0·6252	0·5603	0·5634	0·5521	0·5789	0·5830	0·7169
	Bases solb. in 0·5 N acetic acid (m. e. %)	57 27	58·92	58·92	56·44	58·09	62·62	56·86	53·56
	Calcium solb. in 0·5N acetic acid(m. e. %)	55·21	53·77	52·74	51·09	53·15	57·68	53·56	47·79
	pH	7·3	7·3	7·3	7·3	7·3	7·4	7·3	7·2

EXPERIMENT II

Farm and No. of years.	Items of analysis	(Treatments per acre basis) No manure	30 lbs N	60 lbs N	90 lbs N	120 lbs N	20 lbs P_2O_5	40 lbs P_2O_5	4 cwt lime	8 cwt lime
Chinsura farm 6 years	Organic Carbon %	0·7844	0·7875	0·7917	0·8747	0·9314	0·8757	0·8243	0·8043	0·8117
	Bases solb. in 0·5 N acetic acid (m. e. %)	24·78	24·93	24·82	24·04	23·31	24·61	25·05	24·82	24·78
	Calcium solb. in 0·5 N acetic acid (m. e. %)	17·89	18·35	18·35	17·68	17·47	18·14	18·35	18·35	18·78
	pH	6·5	6·4	6·3	6·1	6·1	6·6	6·5	6·4	6·6
Suri farm 6 years	Organic Carbon %	0·2798	0·2172	0·2616	0·2646	—	0·2404	0·2687	0·2737	0·3121
	Bases solb. in 0·5 N acetic acid (m. e. %)	4·85	5·85	5·66	5·05	—	6·06	5·25	5·66	6·06
	Calcium solb. in 0·5 N acetic acid (m. e. %)	4·20	5·05	5·05	4·61	—	5·05	4·61	5·05	5·45
	pH	6·5	6·6	6·6	6·2	—	6·6	6·4	6·6	6·5
Berhampore farm 5 years	Organic Carbon %	0·5490	0·5438	0·5274	0·5037	—	0·5088	0·4563	0·4614	0·4573
	Bases solb. in 0·5 N acetic acid (m. e. %)	30·08	33·78	31·72	29·66	—	32·96	28·02	32·14	30·90
	Calcium solb. in 0·5 N acetic acid (m. e. %)	25·34	28·02	28·22	24·72	—	28 43	25·34	27·60	24·51
	pH	7·1	7·1	7·1	7·1	—	7·1	7·2	7·2	7·2

DISCUSSION

Effects of Treatments on the Crop

(Single factor effects)

Chinsurah Farm.—Application of ammonium sulphate, bonemeal and farmyard manure increased the yield of paddy grains and straw over no manure. The optimum for nitrogen is the level 30 lbs per acre. Higher doses, increased straw and the plants got lodged and therefore, failed to give higher returns. Bonemeal increased the yield of grains, more so when used alone. Farmyard manure also increased yield. Addition of lime had no effect.

Suri Farm.—Application of ammonium sulphate, bonemeal, farmyard manure and lime increased the yield of paddy grains and straw over no manure. Ammonium sulphate, was most effective followed by farmyard manure, bonemeal and lime. Higher level of nitrogen is required for this trac·.

Berhampore Farm—Application of ammonium sulphate produced more grain and straw Phosphoric acid, lime or farmyard manure are ineffective in increasing production.

Effect of Treatments on Soil

Chinsurah Farm :—The soils of this farm is semi-mature gangetic alluvium. The soil has a clay content of about 50 % on the top, increasing to about 60—65 % below. Calcium has been leached down and has reached, below 2 ft. where the soil is calcareous and effervesces vigorously with hydrochloric acid. The soil is neutral in reaction on the top and contains an average status of phosphate and potash as is found in the locality. It has an angular blocky structure, plastic and sticky. It is hard when dry and cracks.

Continuous application of ammonium sulphate has resulted in a very slight reduction of pH which could be successfully prevented, by liming. Organic matter status of the soil remained the same. The vegetative matter incorporated due to increased growth after application of ammonium sulphate seems to have counterbalanced the increased loss of soil organic matter due to microbial action. Addition of farmyard manure did not build up a higher organic status in the soil, during the short period of observation.

Suri Farm :—The soils of this farm is derived from gneiss of all ages and is situated near a laterite tract. The soil is a coarse sandy loam with a semi-puddled, to loose crumb structure. Leaching of sesquioxide and clay has taken place from the surface soils, which have accumulated in the lower horizon. The sub-soil is a gravelly, locally known as *morrum*. Both potash and phosphate are low, specifically, the phosphate, which is very low in this locality. It is slightly acidic in reaction. The soil is plastic and becomes very hard when dry.

Continuous application of ammonium sulphate has slightly reduced the pH of the soil, which have, however, been corrected by treating with lime. Farmyard manure and phosphates could not check the lowering of pH, by buffer action. Base status is low in these and therefore, application of ammonium sulphate as nitrogenous manure exhibited a greater tendency to produce acidity.

The organic matter status of the soil is not significantly reduced by application of ammonium sulphate, nor did application of farmyard manure increased the soil organic matter during the six year period.

Berhampore Farm.—The soil is a new gangetic alluvium, containing free calcium carbonate in a fine powder from. It is a loamy soil, single grained structure, containing enough potash and phosphates. Nitrogen is low. The pH is neutral. The profile is a thick alluvium without stratification.

Continuous application of ammonium sulphate has no effect on pH. Phosphate or application of lime has no effect on crop or soil.

Organic matter status does not decrease on the application of ammonium sulphate, phosphate or lime. Farmyard manure on the other hand has increased the organic matter of this soil type.

ACKNOWLEDGMENT

Thanks are due to Dr. S. K. Mukherjee, Agricultural Chemist, West Bengal, for his kind help in writing out this paper.

STUDIES ON FACTORS AFFECTING SOIL FERTILITY IN THE SUGAR BELT OF BIHAR

VII—EFFECT OF SOLUBLE SALTS ON PHOSPHATE AVAILABILITY

By

K. L. KHANNA, P. K. ROY *and* H. R. DUBEY

Central Sugarcane Research Station, Pusa, Bihar

Communicated by Dr. S. P. Mitra

(*Received on 3rd November, 1954*)

I. INTRODUCTION

The interdependence of phosphate availability and soil reaction has been discussed by Gaarder and Grachl Nielson[1,2] Austin[3] and Naftel[4]. They have shown that iron and aluminium were the dominant ions in the precipitation of phosphates at pH values below 5·5, while calcium becomes active as the pH approached 6·0, the effect being dominant at a pH of over 6·4. Magnesium ions have also been shown by them to become operative in the precipitation of phosphates at a pH of about 7·5. Reviewing the results of long term field experiments at Wooster, Ohio, Barnes[5] concluded that the crop yield could be maintained at a economic level with minimum investment in phosphatic fertilizers, provided the soil reaction was maintained at a pH in the neighbourhood of 7·5.

The particular form of phosphate ion absorbed by plants according to Buehrer[6] appears to be governed mainly by soil reaction. At alkaline pH, PO_4''' ions predominate which are least readily absorbed by plants. As the pH is lowered the HPO_4'' and H_2PO_4' ions prevail, while at higher acidities the H_2PO_4' ions dominate. These two forms of phosphate are readily absorbed by plants.

On the other hand, from a consideration of the effect of soluble salts on phosphate solubility, McGeorge *et al*[7] came to the conclusion that a limiting concentration of 0·05 N of neutral salts affects the solubility of dicalcium phosphate at any particular pH. The depressing effect of high concentrations of soluble salts on phosphate solubility under a particular pH has also been studied by Roy.[8]

The broad soil divisions in the white sugar belt of Bihar have been shown by Prasad and others,[9] to exhibit a pH range of 6·4 to 9·0, while the distribution of soluble salts over the tract has been found to vary over a considerable range depending on soil character and climate. In the present work an attempt has been made to study the availability of phosphates under varying salt concentration at definite pH ranges.

II. MATERIALS AND METHODS

Prasad, *et al* (loc. cit.) showed that the non-calcareous soil divisions in the sugar belt of Bihar is characterised by a low concentration of soluble salts and a reaction range showing variation of pH from 6·4–7·5 ; while the calcareous soils was shown to contain a higher concentration of soluble salts with a pH variation from 8·4–9·0. The heavy clay division, on the other hand was found to contain variable amounts of soluble salts within a wider pH range, *viz.*, 6·4–8·4. In the present work, availability of phosphates in the soils of the tract has accordingly been studied under the following categories of soil pH and soluble salt concentration :—

Soluble salt content	pH range 6·4—7·5	pH range 7·5—9·0
Low	Less than 150 mgm/100 gm soil	Less than 150 mgm/100 gm soil
Normal	Between 150—200 mgm/100 gm soil	Between 150—200 mgm/100 gm soil
High	Above 200 mgm/100 gm soil	Above 200 mgm/100 gm soil

Surface soil samples collected during the intensive and detailed surveys of sample areas covering the broad non-calcareous, calcareous and heavy clay divisions were utilised for the purpose. The samples were air dried, crushed and sieved through 2 mm seive.

pH of soil suspension.—The pH values were determined by using the glass electrode with Cambridge pH meter in the suspension ratio of 1:2·5 after shaking for an hour.

Determination of soluble salts.—Soil and CO_2 free water in the ratio of 1:5 were kept overnight with occasional shaking, filtered, aliquot dried and weighed.

Acid soluble phosphates.—Modified Van Bemmelen- Hissink method, recommeded by the Agricultural Association in 1931, was adopted[10,11]. The ratio of soil : hydrochloric acid (constant boiling point) was 1:10 and time of extraction by boiling was one hour. Phosphate was estimated by Pemberton's Phosphomolybdate titration method[20,21].

Available phosphate.—Of the several existing methods for the extraction of soil phosphate[12,13,14,15], Ensminger's[16] extracting process was adopted due to the following reasons :—

(1) The general soil pH varied from nearly neutral to strongly alkaline range in the soils under examination.

(2) The condition of extraction by CO_2 simulate the mechanism employed by plants in the extraction of soil phosphorous under field conditions.

Available phosphates were estimated colorimetrically by Denige's method modified by Holman and Pollard[17], Holman[18] and lately by Yuen[19].

Percentage Availability.—Percentage availability was expressed as the ratio

$$\frac{\text{Acid soluble phosphate}}{CO_2 \text{ extractable phosphate}} \times 100$$

III. DISCUSSION OF RESULTS

The frequency distribution of available phosphates (expressed as percentage of the acid soluble phosphate) has been shown in Table I for the two ranges of pH value under three different categories in relation to soluble content, *viz.*, high, normal and low.

TABLE I

Showing percentage available P_2O_5 *under different levels of total soluble salts in the soil*

pH 6·4—7·5

% P_2O_5 availability / Total soluble salts (mgm/100 gm soil)	Up to 1·0 Frequency.	% T	1·0—5·0 Frequency	% T	5·0—10·0 Frequency	% T	10·0—15·0 Frequency	% T	Above 15·0 Frequency	% T	Total Frequency	% T	*Mean
Below 150 (Low)	3	7·7	3	7·7	17	43·6	6	15·4	10	25·6	39	100	11·87±1·35
150-200 (Normal)	2	6·1	5	15·1	24	72·7	2	6·1	...	...	33	100	6·58±0·52
Above 200 (High)	10	37·0	5	18·4	10	37·0	1	3·8	1	3·8	27	100	4·29±0·99

pH above 7·5

% P_2O_5 availability / Total soluble salts (mgm/100 gm soil	Up to 1·0 Frequency	% T	1·0—5·0 Frequency	% T	5·0—10·0 Frequency	% T	Above 10·0 Frequency	% T	Total Frequency	% T	Mean
Below 150 (Low)	12	40·0	9	30·0	6	20·0	3	10·0	30	100	4·30±1·27
150-200 (Normal)	15	75·0	1	5·0	1	5·0	3	15·0	20	100	3·49±1·55
Above 200 (High)	17	53·2	14	43·7	1	3·1	...	...	32	100	1·45±0·27

It will be seen that 84·6, 78·8 and 44 6 % of the total frequencies come under the phosphate availability level of about 5·0 % (not very low) in case of low, normal and high soluble salt categories. Under pH range 6·4—7·5, the corresponding values in the pH range 7·5—9·0 being 30·0, 20·0 and 3·1 % respectively. This clearly brings out the depressing effect of increasing soluble salts concentrations on phosphate availability under both pH ranges besides the similar and much more marked effect of high pH. Statistically, phosphate availability is significantly higher in case of low soluble salt category as compared to both normal and high groups in the pH range 6·4—7·5 while in the range 7·5—9·0, the difference is significant between the low and high categories only.

IV. SUMMARY

(1) Phosphate availability in soils of the sugar belt of Bihar has been studied in relation to different levels of soluble salt contents under two different ranges of pH (6·4—7·5 and 7·5—9·0).

(2) Higher concentrations of soluble salts tend to depress availability of phosphates under any particular range of pH value.

(3) Phosphate availability appears to be higher in the pH range 6·4—7·5 as compared to one of 7·5—9·0.

V. ACKNOWLEDGMENT

The authors are indebted to the Government of Bihar and the Indian Central Sugarcane Committee for jointly financing the Sugarcane Research Scheme in Bihar of which the present work forms a part. The assistance rendered by Sri R. C. Acharya, M.A., in statistically analysing data presented here is also acknowledged.

VI. REFERENCES

1. Gaarder, T., (1930) : *Mead. Vestlanddets forst, Forsokssta,* **14**, 1.
2. Gaarder, T., and Grachl-Nielson, (1935) : *Ibid,* **18**, 1.
3. Austin, R. H., (1927) : *Soil Sci.* **24**, 263-7-0.
4. Naftel, J. A., (1936) : *J. Amer. Soc. Agron.* **28**, 740—52.
5. Barnes, E. E. and Salter, R. M., (1953) : *Ohio Agr. Exp. Sta. Bull. No.* 553.
6. Buehrer, T. F., (1932) : *Arizona Agric. Exp. Sta. Tech. Bull. No.* 42.
7. McGeorge, T., Buehrer, T. F. and Breazeale, J. F., (1935) : *Jour. Amer. Soc. Agron.* **27**, 330—35.
8. Roy, P. K., (1935) : *Thesis submitted for the Diploma of the Imperial College of Science and Tech., London.*
9. Prasad, S. N., Bhattacharya, P. B. and Sinha, S. D., (1951) : *Proc. 1st. Biennial* Conference Sug. Res. Workers, Part II-4, pp. 36—51.
10. Knowles, F. and Watkin, J. E., (1937) : *A practical Course in Agricultural Chemistry, MacMillan & Co. Ltd., London.*, p. 33.
11. Piper, C. S., (1944) ; *Soil and Plant Analysis, University of Adelaide,* p. 140.
12. Dyer, B., (1894) : *Trans. Chem. Soc.* **65**, 115—67.
13. Truog, E., (1930) : *J. Amer. Soc. Agron.* **22**, 874—82.
14. Das, S., (1926) : *Mem. Dept. Agr. India Chem. Ser.* 8, *No.* 6.
15. Das S., (1930) : *Soil. Sci.* **30**, 33—49.
16. Ensminger, L. E. and Larson, H. W. E., (1944) : *Soil Sci.* **58**, 253—58.
17. Holman, W. M. and Pallard A. G., (1937) : *J. Soc. Chem. Ind.* **56**, 339-43.
18. Holman, W. M., (1938) : *Ph.D. Thesis London University.*
19. Yuen, S. H., (1948) : *Ph.D. Thesis London University.*
20. Pemberton, H., (1893) : *J. Amer. Chem. Soc.* **15**, pp. 382—395 :
21. —— *J. Amer. Chem. Soc.* 16, pp. 278-282.

CHEMICAL SOIL CONDITIONERS

By

C. L. DHAWAN, B. K. HANDA *and* BALBIR VERMA

Irrigation and Power Research Institute, Punjab, Amritsar

(Received on 29th October, 1954)

It has been well recognised by the scientists that soil structure is the key to soil fertility. The response of different crops to fertilisation depends upon a favourable soil structure.

In a number of recent papers the effect of synthetic poly-electrolytes on the aggregate aeration and water relationships of soils has been investigated. The different poly-electrolytes being investigated by the various workers are the following :—

(1) CRD 186.

(2) CRD 189.

(3) Krilium.

(4) Belgium poly-electrolyte resin.

(5) HPAN (Hydrolysed polyacrylonitrile).

(6) VAMA (Vinyl acetate Maleic acid).

(7) Callulose gums, Silicates and lignin derivatives.

Peter and his co-workers[11] worked on CRD 186 and CRD 189. Their conclusions were that additions of as much as 0·2% by weight of CRD 186 and CRD 189 to soils varying in texture from sandy loam to clay did not increase their moisture equivalents. Adding large amounts of these conditioners at rates as high as 0·4% caused some increases in moisture equivalents particularly with the coarse textured soils. They were of the opinion that the application of synthetic poly-electrolyte conditioners did not appear to offer a practical means of increasing the amount of available moisture held by a unit quantity of soil.

Krilium was tried by Gordon[6], Vallance[10], Free[5] Martin[9,10] Slater[15], Swanson[15], Kuipers and Boekel[8].

Gordon[6] came to the conclusion that krilium improved the structure of silt-loam and clay-loam, but produced only a doubtful improvement in another clay-loam. Free's[5] results indicated that krilium was less effective than straw-mulch in increasing the ratio of infiltration to run-off under continued exposure to natural rainfall. Slater[14] sought to determine the effect of varying temperatures on the stability of soils treated with krilium. It was found out by him that the water stability of naturally structured soils tended to increase as the drying temperature increased, but that of krilium treated soils did not alter with temperature (the range of temperature used by him was from 40°—180°F).

Martin[9,10] concluded that the rates of application of krilium appeared to be effective in the range of 0·02 to 0·2% of active chemical depending mainly on need and method of incorporation. Swanson[15] reported that krilium was most effective on a loamy sand. Increasing amounts of krilium improved aggregation of all the soils, but repressed the plant growth and often retarded germination.

Sherwood[13] studied the effect of VAMA and HPAN on the physical, chemical and biological condition of the soil. The incorporation of these chemicals produced improved workability, reduced crusting, effective control of erosion and beneficial effects on crops. Gordner's[7] results showed conflicting evidence on their effects on the available moisture and plant growth.

In view of the conflicting evidence presented by the different workers, it was considered desirable to study the behaviour of krilium in the different types of soils, in order to investigate its beneficial effects and its limits of applicability. Krilium polymer is a water soluble resin. It is claimed to be a synthetic replacement for the natural poly-saccharide or poly-uronide resins derived from humus.

EXPERIMENTAL

The following investigations were carried out :—

(*i*) Effect of varying percentages of krilium on the degree of dispersion of different types of soils.

(*ii*) Effect of ageing on the degree of dispersion of soils containing varying percentages of krilium.

(*iii*) Effect of moisture content present in the soil on the degree of dispersion of soils.

DISCUSSION OF RESULTS

(*i*) *Effect of varying percentages of krilium on the degree of dispersion of different types of soils*

Three types of soils having the following mechanical composition were selected for this study.

Sr. No.	Soil No.	Clay % (Particles below 0·002 mm)	Silt % (Particles greater than 0·002 mm but less than 0·02 mm)	Sand % (Particles greater than than 0·02 mm but less than 2·0 mm)
1.	104	13·68	25·76	60·52
2.	105	50·08	19·76	30·12
3.	106	27·20	30·68	42·44

The following percentages of krilium were added to them and the clay percentage was determined by dispersion in water only (auto-disintegration).

Fig. I presents the effect of the addition of krilium on the dispersion coefficient of soils. The graph is drawn on semi-logarithmic scale. Dispersion coefficient is the ratio between the percentage of clay on auto-disintegration to the total clay on complete dispersion (Puri, 1930). The higher the value of dispersion

coefficient the more impeded the movement of water through that soil would be.

Dhawan[4] was of the opinion that the structure of the soil was mainly governed by the dispersion coefficient.

The following conclusions were drawn from Fig. I.

(*i*) The lowest dispersion was observed in soil No. 104 (clay content 13 66%), when the percentage of krilium admixed was between 0·001 to 0·01%.

(*ii*) In the case of the other two soils possessing clay content of 27·2% and 50·08%, the lowest dispersion was affected in the range of 0·05% to 0·01% of krilium.

(*iii*) The effects of krilium treatment are apparent due to the formation of stable clay aggregates which have resulted in less dispersion in water due to the increase in the non-capillary porosity. It is well-known that the non-capillary porosity contributes to drainage and aeration, as the permeability of a soil is related with the non-capillary porosity[1]

(*iv*) The second experiment was conducted to investigate the effect of ageing on the degree of dispersion of soils containing varying percentages of krilium

Soils No. 105 (clay content 50·08 %) and No. 106 (clay content 27·2 %) were selected for this study. The dispersion coefficient of soils was determined immediately, after one day, two days, three days, four days, five days, six days, one week, two weeks and one month interval. During this period the soils were kept under saturation. The results of dispersion coefficient are embodied in the table below :—

TABLE No. I

Showing the effect of ageing on the dispersion coefficient of Soils

Percentage of krilium added	Dispersion coefficient: Immediately	1 day	2 days	3 days	4 days	12 days
Sample No 105						
0·001	43·0	44·5	45·5	44·0	43·5	42·5
0·005	42·5	44·5	44·5	44·0	43·5	43·0
0·010	14·0	16·5	18·0	20·8	18·0	15·0
0·050	9·0	9·5	10·0	9·5	9·5	9·0
0·100	9·0	10·0	9·5	9·5	9·5	9·5
0·500	20·0	22·5	23·5	24·5	25·5	25·0
1·000	35·0	37·5	38·5	38·5	40·0	41·0
Sample No. 106						
0·001	17·5	18·5	18·0	18·0	17·5	17·5
0·010	11 0	12·5	11·0	11·5	11·0	11·0
0·050	7·0	7·5	8·0	7·5	7·5	7·0
0·100	4·5	5·0	5·5	6·0	6·0	6·5
0·500	5·0	6·0	6·5	7·0	7·5	8·0
1·000	23·0	24·5	25·6	26·6	27·1	27·8

A moment's reflection at the above table showed clearly that the effect of the krilium was immediate. The conditioner being not nutrient did not require any time for undergoing transformation.

(*iii*) The third experiment sought to determine the effect of the initial moisture content on the dispersion coefficient of soils treated with varying percentage of krilium.

Soil No. 105 (clay content 50·08%) was chosen for this investigation. The percentage of krilium added was from ·001% to ·400% and the moisture content was kept at 5·0%, 10·0% 15·0% 20·0% and super-saturated. The dispersion coefficient was determined after one day, two days, one week, two weeks, three weeks, and four weeks of the admixing of krilium with the soil. The results are given in the table below :—

TABLE No. II

Showing the effect of initial moisture content of soils on the dispersion coefficient

Dispersion-coefficient of soils at varying moisture contents

Sample No. 105

Percentage of krilium added	5%	10%	15%	20%	Super stura-ration	Period
0·005	40·50	36·00	38·50	40·00	40·50	1 day
0·010	14·50	15·60	15·00	13·50	12·50	
0·050	14·00	10·50	10·50	9·00	9·00	
0·100	13·00	11·00	10 50	10·50	10·00	
0·400	17·00	15·37	15·52	10·12	15·12	
0·005	37·50	39·00	40·50	42·00	41·00	2 days
0 010	21·00	15·95	16·05	14·57	14·57	
0·050	14·00	15·95	16·52	15·03	12·10	
0·100	13·50	11·55	10·56	11·02	10·50	
0·400	17·50	16·12	16·12	16·56	16·00	
0·005	37·56	39·12	40·42	40·76	40·24	1 week
0·010	18·76	15·64	15·48	14·12	13·56	
0·050	12·56	11·48	11·56	12·42	10·84	
0·100	12·12	11·16	10·56	10·24	10·12	
0·400	16·76	15·84	15·84	15·76	15·96	
0·005	36·64	37·56	38·42	39·56	40·00	2 weeks
0·010	19·12	14·56	12·75	12·56	12·48	
0·050	12·36	11·24	10·48	9·46	9·24	
0·100	12·76	11·56	10·48	10·28	10·12	
0·400	16·64	14·44	16·24	15·24	15·28	
0·005	35·56	37·24	38·12	39·24	39·75	3 weeks
0·010	18·76	14·12	12·56	12·56	12·55	
0·050	12·24	10·56	10·24	9·36	9·12	
0·100	12·86	10·68	10·84	9·88	9·76	
0·400	16·24	15·56	15·04	14·56	14·56	
0·005	35·24	38·64	39·24	38·48	39·56	4 weeks
0·010	10·24	12·12	12·24	12·18	12·28	
0·050	10·56	8·96	8·76	8·56	8·56	
0·100	10·40	9·64	9·78	9·56	9·48	
0·400	16·04	14·33	14·44	14·48	15·12	

It was inferred from the above results that the effect of moisture content from 5·0% to super-saturation was not very significant. This showed that the krilium could be used effectively even at very low moisture content *i.e.*, 5%.

Summing up the results of the above experiments, we came to the conclusion that krilium made the clayey soils more pervious which meant an increase in the non-capillary porosity and the air capacity.

It is an accepted fact that sufficient aeration is one of the major problems for good plant growth on clayey soils and the air capacity of such types of soils can be increased by the addition of organic matter, cinders or sand. The results of the above experiments also showed that the admixture of 0·05% to 0·1% krilium also performed the same object.

The main question to be answered before recommending its use is to compare its utility and economics with the green-manures which are commonly employed for improving the structure of a soil.

It was brought out by Dhawan and his collaborators[2,3] that green-manuring could be used for the amelioration of alkali soils. The question naturally arises, whether a chemical soil conditioner (krilium) can be used for the reclamation of alkali soils.

Alkali soils are well-known to possess the following characteristics :—

(*i*) High pH value.

(*ii*) High percentage of exchangeable sodium.

(*iii*) Low percentage of exchangeable calcium.

(*iv*) High dispersion-coefficient.

The barrenness of these soils is due to the adverse physical conditions induced by an excess of exchangeable sodium and a deficiency of calcium brought about by the excess of hydroxyl ions. How far krilium can treat such like deteriorated conditions in a soil ? The answere is not for to seek.

Our experiments have proved that 0·05 to 0·1% krilium can improve the texture of the soils. But the pH of water solutions at different concentrations at 25°C of krilium is follows :—

Concentration 0·1%, 0·5%, 5·0%.

pH of water solution 9·6, 9·0, 8·2.

The main consideration in the reclamation of alkali soils is the replacement of Na by Ca. But at such high pH values calcium carbonate usually present in the alkali soils of arid and semi-arid zones cannot be made available. The only advantage in using krilium will be the improvement in physical conditions of the soils at the surface, which may help in establishing rice seedlings. If the rice seedlings are established, carbon dioxide is released from the roots of the plants, whose pH in the water solution is about 4·0 and at that pH value calcium carbonate is soluble which will gradually replace Na in the exchange complex. A separate paper is being contributed shortly on the semi field experiments being carried out with different doses of krilium.

A word about the cost of its application will not be out of place. The quantity of krilium required on one acıe plot on the basis of 0·05% comes to

about 500 pounds. The present cost of this chemical is Rs. 10 per pound. Therefore the total cost of krilium for one acre plot will be about Rs. 5,000, which is prohibitive and *secondly* the advantages are limited.

The use of green-manuring has treble advantage. *Firstly* it does not cost much to the cultivator, *secondly*, during its decomposition, it releases complex organic acids, which lower the pH of the soils and bring about the replacement of Na by Ca and *thirdly* it improves the structure of the soil and adds certain essential nutrients necessary for maintaining the fertility of a soil (Dhawan, loc cit.).

SUMMARY

(*i*) A chemical soil conditioner like krilium 0·05% to 0·1% may be used for improving the physical structure of barren types of clayey soils. But its cost is prohibitive at the present rates.

(*ii*) Comparing with green-manuring the use of krilium falls short of many advantages. Being of high pH value, it cannot help directly in the replacement of Na by Ca, which is very essential for the reclamation of alkali soils.

(*iii*) Green manuring releases complex organic acids which apart from lowering the pH of the alkali soils also add essential nutrients *i.e.*, nitrogen, which directly maintains the fertility of a soil.

(*iv*) The use of chemical soil conditioners should be recommended with caution and proper judgment.

REFERENCES

1. Burger, H., 1926. "Die physikalische, Bqdenutersuchung inbesonderedic methoden zur Bestimmung der Luftkapazitat". *Proc. 4th. Intern. Conf. Soil Sci.*, **2**, 150—163.

2. Dhawan, C. L., Bhatnagar, B. B., Sharma, R. N., and Amrik Singh, 1952. Reclamation of Alkali Soils." *Annual Bulletin of International Commission on Irrigation and Drainage*, p. 25.

3. Dhawan, C. L., Malhotra, M. M. and Jagir Singh, 1953. "Reclamation of Alkali Soils. Jantar (Sesbania Cannabina) Root system in black alkali soils treated with different Reclaiming agents." *Annual Bulletin of International Commission on Irrigation and Drainage*, p. 87.

4. Dhawan, C. L. and Sharma, R. N., 1950. "Structure of the Punjab Soils." *Ind. Jour. Agric. Sci., Vol. XX, Part IV.* p. 461—478.

5. Free, G. R., 1953, "Compaction as a factor in Soil Conservation." *Proc. Soil Sci. Soc. Amer.* **17**, 68—70.

6. Gordon, M. 1952. "*Experiments with krilium Torfnachrichten*, **3**, 13-14, *C. A. 47 (4537) (GI), zwise henahn, Germany.*

7. Gordner, W. H., 1952. "Synthetic Soil Conditioners and some of their uses." *Proc. Wash. St. Hort. Ass.* **48**, 115—122 (*Wash. St. Coll.*).

8. Kuipers, H, Boekel, P., 1952. *Resultaten ven een laboratorium Onderzoek naar de, working van krilium Landbouwk, Tisdschr.*, b. **4**, 931—735.

9. Martin, W. P., 1952., Volk, G. W., 1952. Soil Conditioners and Fertilizers. *First Rev.* **27**, No. **4**, 11—13.

10. Martin, W. P., 1953. Status report on soil conditionering Chemical—I *Proc. Soil Sci. Soc. Amer.* **17**, 1—9.

11. Peter, D. B. Hagan, R. M. Bodman, G. B., 1953. Available moisture capacities of soils as affected by additions of poly-electrolyte Soil Conditioners. *Soil Sci.* **75**, 467—47.

12 Sherwood, L. V., and Engibouse J. C., 1953. "Status report on Soil Conditioning Chemicals II." *Proc. Soil Sci. Soc. Amer.*, **17**, 9—16.

13. Puri, A. N. 1930., *Mem. Dept. Agric. Imp. Inst. Agri. Res. XI* (2).

14. Slater, C. S., 1953. Effect of sample drying on the determination of the water stability of Soils. *Soil Sci. Soc. Amer.* **17**, 75—76.

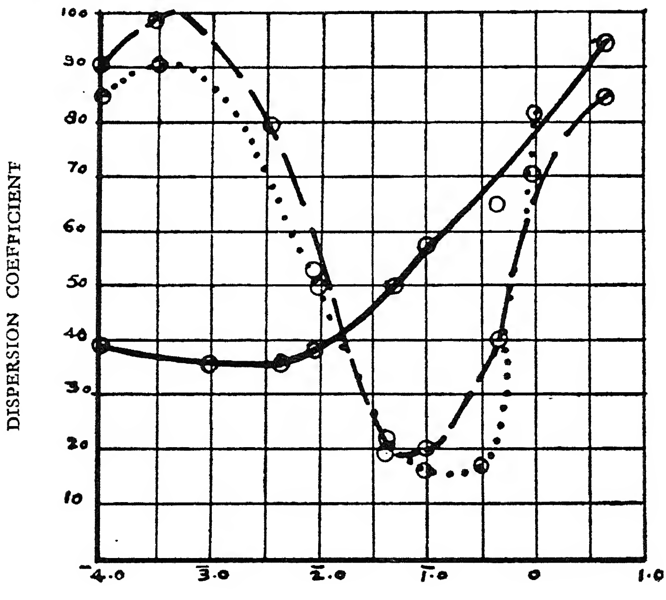
15. Swanson, C. L., W. 1952. "Soil Conditioners awaken New interest in Soils." *Froutiers Pl. Sci.* 5 Nov., 4—5.

16. Vallance, L. G., Leverington, K. C. 1953. "The effect of Krilium on some sugar cane soils." *Cane-drow Quart Bull.*, **16**, 117—102.

Effect of adding varying percentages of krilium on dispersion coefficient of soils

(semi-logarithamic scale)

1.	Sample No. 104	Clay 13·66%	————
2.	,, 105	,, 50·08%	— — — —
3.	,, 106	,, 27·2%	... ...



"MINERALS, MICROBIAL ACTIVITIES AND CROP-PRODUCING POWERS OF SOILS"

By

N. V. JOSHI *and* Miss M. M. VARTAK

Maharashtra Association for the Cultivation of Science, Poona

Communicated by Prof. S. Ghosh

(*Received on 5th October, 1954.*

It is well-known that a number of various factors contribute to the crop producing power of the soil and it is naturally expected that a certain amount of correlation would be found among them and if this correlation is known and could be determined before sowing the crop, it is very likely that the crop producing power or fertility of a soil could be predicted beforehand and in case some defects are discovered, they could be remedied and set right so that the proper correlation between the different factors is re-established and the crop producing power of the soil is restored to its normal level.

It was proposed to study the mineral composition of soils and the bio-chemical and physiological activities of micro-organisms in some representative soils in the region of Maharashtra in the Bombay State and see whether there is any correlation between mineral constituents and micro-biological activities of these soils because these micro-biological activities in soils are concerned with the supply of nutrients to plants by making insoluble minerals into soluble products, as well as with the decomposition of insoluble organic matter and its mineralisation and thereby making it available to the plants.

It was also further proposed to find out whether the crop producing power of these soils is in any way related to or governed by the minerals present in these soils and the microbial activities occuring in them. In other words the object of the investigation was to see whether there is any "correlation among the mineral constituents, micro-bioloigcal activities and fertility or crop producing power of some soils in the Bombay State.

For this purpose it was proposed to bring four types of soils derived from different kinds of parent rocks :—

(*i*) Black cotton soil derived from Deccan trap, (*ii*) lateritic soil derived from laterite, (*iii*) soil from limestone region derived from limestone, and (*iv*) granitic soil derived from granite-gneiss, and to examine the soils for their (*i*) mineral constituents by the method described by Aurther Holmes in his book of "Petrographic Method" and to study clay minerals of these soils by X-ray diffraction method, and for their (*ii*) micro-biological activities such as oxidation of nitrogen and carbon in producing nitrates and carbon dioxide and also to determine the number of bacteria in the soils and for their (*iii*) crop-producing powers.

In determining the fertility of the soil by growing crops, addition of organic matter to the soil in the form of oil-cake or farmyard manure is usually made, but such addition of organic matter to the soil was particularly avoided in our experiments, because it was our deliberate intention to see the effect of the activities of the micro-organisms and of the decomposition of minerals existing in the soil and see and compare their natural crop-producing powers. If the organic matter were to be added to the soil, it would have brought out only the correlation between micro-biological activities and soil fertility but not the relation between the minerals existing in the soils and their correlation to the natural fertility of the soil because it is well known that the organic matter is decomposed by the soil organisms at a relatively rapid rate while the mineral particles are decomposed usually at a comparatively slow rate and hence when growing crops, the addition of organic matter to the soils would bring out the effect of the rapid decomposition of organic matter by microbial activities into greater prominence and would mask the effect of the comparatively slow decomposition of minerals, while our main object was to find out whether micro-biological activities effect any change in the mineral constituents and if so whether such decomposition of minerals in the soils by microbes——affects in any way the crop-producing power. In other words it was our objects to see whether any correlation exists among microbial activities, mineral constituents and natural crop-producing power of soils in Maharashtra without addition of any manure to the soils.

METHODS EMPLOYED IN THE INVESTIGATION

(1) *Mechanical analysis.*—Mechanical analysis was carried out by the "Agricultural Education Association" method as modified by G. W. Robinson[1] (pretreatment being with HCl, H_2O_2 and dispersion with caustic soda instead of ammonia) as described by C. H. Wright[2] in his book of "Soil Analysis," 1934, London, pp. 33—36.

(2) *Hygroscopic moisture.*—The method used for determining hygroscopic moisture is described by C. H. Wright[2] in his book "Soil Analysis", 1934, London, p. 37. The details of the method are given below :—

Weigh 10 gm of air-dried soil in a wide weighing bottle and heat for 24 hours at 105°C, then cool in a dessicator and re-weigh. Heavy clay soils and those containing an appreciable amount of organic matter should be replaced in the oven for a further period of 24 hours and a second weighing should be made.

(3) *Carbonates.*—The method used is described by C. H. Wright (Soil Analysis, 1934, p. 136). Carbonateswere determined by Collin's Calcimeter. Instrument designed by S. H. Collins[3].

(4) *Organic matter.*—This was determined by the loss on ignition method as described by C. H. Wright.[2] (Soil Analysis, 1934, p. 11).

(5) *Hydrogen iron concentration.*—This was determined by the method described by C. H. Wright[2] (Soil Analysis, London, 1934, p. 56) and in which Quinhydrone Electrode was used as described by E. Biilmann and S. Tovborg Jensen.

(6) *Water holding capacity.*—This method used is described by C. H. Wright "Soil Analysis" London, 1934, p. 2. Water holding capacity was estimated by procedure described by B. A. Keen and J. R. H. Coutts[4] using perforated brass dishes with screwable rings.

Mineralogical Analysis.—This was carried out by the method described by Aurther Holems[5] in his book "Petrographic Method" pp. 66 to 70, 1920 and 1935.

Analysis of clay minerals.—Clay fraction was obtained from soils by "Sharples" super-centrifuge (turbine drive). This portion was then treated with glycerine and then analysed by X-ray diffraction method as carrid out by Ross and Kerr.[6]

(II) MICROBIAL ACTIVITIES

CO_2 evolution and nitrification.—For studying CO_2 evolution and nitrification of the soil known definite quantities of organic manure and water were added to the soils and CO_2 was measured every day and nitrates, nitrites and ammonia were determined every week. The methods used for these were the well-known standard methods used in the Indian Agriculture Research Institute, New Delhi.

Bacterial counts.—Bacterial counts were made by the plate method which, gives us a fairly good comparative idea of the numbers in the different soils examined by us in our investigation.

(III) CROP-PRODUCING POWER

Pot culture experiments were carried out for the purpose. Four pots were used for each of the soils to grow the crops. Two crops wheat and jawar were grown in the pots one after the other in succession. The plants in all the pots received similar treatments (watering, exposure to the sun, etc.) throughout their growing period. After they attained full growth they were removed from the pots and the total yields of the crops were measured.

EXPERIMENTAL RESUTLS

The results obtained by the mechanical analysis of the soils and determining hygroscopic moisture, carbonates organic matter, pH, etc., are given in tables No. I(*a*) and (*b*). These figures in the tables give a general idea about the physical nature of the soils.

EXPERIMENTS No. 1

Mechanical Analysis.—(*a*) Mechanical analysis of these soils was carried out for finding the physical nature of the soils.

(*b*) Hygroscopic moisture, carbonate, organic matter, hydrogen ion concentration *i.e.*, pH, and water-holding capacity, were determined by the methods described previously.

Some of these factors were determined to get additional information about the physical nature of the soils. The acidities or alkalinities of the different soils were found out by determining hydrogen-ion-concentration so as to be useful for comparing and correlating them with the micro-biological activities of th soils.

The results of experiment No. 1 (*a*), (*b*) are given in Tables No. 1(*a*) and 1(*b*).

TABLE No. 1(*a*)

Soils	%coarse sand	%fine sand	%silt	%clay
Black cotton	18·70	35·99	14·86	20·66
Lateritic	31·60	21·80	18·70	15·30
Limestone	9·98	37·98	21·35	12·04
Granitic	13·53	15·54	14·17	46·80

TABLE No. 1 (*b*)

Soils	% moisture	% carbonates	% organic matter	pH	% water-holding capacity
Black cotton	5·85	1·24	2·70	8·03	68·06
Lateritic	4·36	0·29	7·95	6·88	59·79
Limestone	7·30	3·37	7·98	8·45	64·94
Granitic	5·42	0·64	3·90	7·77	53·53

Figures in the Table No. 1 show that the lateritic and granitic soils contain a low percentage of carbonates than the remaining two. The reactions of the lateritic and granitic soils are near about the neutral and slightly alkaline respectively while the reaction of both the limestone soil and black cotton or Deccan trap soil is definitely alkaline. The water holding capacity of the lateritic and granitic soils is slightly less than that of the other two soils.

The results of the mineral composition of the soils as determined by the method described in the book "Petrographic Methods" are given in Table No. 2.

TABLE No. 2

Minerals in soils

Percentage of— Heavy minerals in soil	Light minerals present
Black cotton soil	
0·34% Augite= (Ca (MgFe) Si_2O_6 Al_2O_3) 0·06 Iron ore—Fe_2O_3	Plagioclase=$Ab_{50}An_{50}+Ab_{30}An_{70}$ Where Ab =Na_2O Al_2O_3 6 SiO_2 and An =CaO Al_2O_3 2 SiO_2 Zeolite=Hydrated silicate of calcium and aluminium Quartz =SiO_2 Chalcedony=SiO_2 Opal =SiO_2+$2H_2O$ Grains of minerals occasionally coated with green or brown Palagonite=Composition variable.
Lateritic soil	
1·2 Augite= (Ca (MgFe) Si_2O_6 Al_2O_3) 0·62% Iron ore=Fe_3O_3 0·18% Palagonite= Chemical composition variable.	Plagioclase=$Ab_{50}An_{50}+Ab_{30}An_{70}$ Where Ab =Na_2O Al_2O_3 6 SiO_2 and An =CaO Al_2O_3 2 SiO_2 Palagonite =Green earth Quartz =SiO_2

Limestone soil

0·11% Iron ore
0·8% ilmenite $=FeOTiO_2$
·03% Hematite= Fe_2O_3
0·019% Epidote=
$Ca\,(AlOH)\,(AlFe)_2\,(SiO_4)_3$
0·009% Hornblende=
$Ca\,(MgFe)_3\,Si_4O_{12}+Al_2O_3$
0·0045% Tourmaline=
Boron silicate of Al.
0·0045% Zircon$=ZrSiO_4$
Augite+Garnet+Biotite
+Rutile=0·013%

Rounded grains of Quartz only$=SiO_2$

Granitic soil

1·95% Iron ore$=Fe_2O_3$
0·61% Epidote=
$Ca\,(AlOH)\,(AlFe)_2\,(SiO_4)_3$
0·022% Zircon$=ZrSiO_4$
0·013% Biotite=
$Si_6\,(AlFe)_6\,(KH)_6O_{24}Si_5\,(MgFe)_{12}O_{24}$
0·013% Hornblende=
$Ca\,(MgFe)_3\,Si_4O_{12}+Al_2O_3$
Augite+Muscovite+Rutile
+Tourmaline=0·59%

Quartz$=SiO_2$
Orthoclase$=(KNa)_2\,Al_2Si_6O_{16}$
Microcline$=K_2O\,Al_2O_3\,6\,SiO_2$

Remarks on Table No. 2.—In the geological method the percentage of any heavy mineral is calculated on the actual number of the mineral grains found under the microscope, but the total number of grains of all the heavy minerals in all the four soils as given in the Table No. 2 are calculated on the basis of 100 gms soil.

It seems from Table No. 2 that iron ore and augite (heavy minerals) are present in all the four soils. Augite is not present in the parent rocks of limestone and granite-gneiss soils but it appears to be found in some soils formed from limestone and granite-gneiss as an impurity and not as a chief soil constituent. Quartz (light mineral) is present in all the four soils.

Results given in Table No. 2 do not supply the information about the minerals in the clay portion of the soils because for determining the heavy minerals it is necessary to remove the clay portion of the soil. So, for getting the clay fraction of the soils, each of the four samples of soils, was first passed through Sharples super-centrifuge (Turbine driven).

The clay portions of the soil types obtained after centrifuging the soils were treated with glycerine so as to get distinct peaks in the X-ray diffraction method previously used by Rose and Kerr.

The results obtained by X-ray diffraction analysis may be summarised as follows :—"The montmorillonite type of clays normally give a strong diffraction peak at about 14 A. This peak was given by the black cotton soil, granitic soil and to a certain extent by the limestone soil. This only suggests that these soils

may contain montmorillonite to a certain extent." Lateritic soil does not give any distinct peak and so we are unable to draw any definite conclusion about the nature of its clay portion without chemical analysis, which we had not carried out.

Experiments on micro-biological activities : CO_2 evolution.—The amount of CO_2 evolved from the soil gives a measure of the capacity of the soil for oxidizing carbon contained in the organic matter and indicates the comparative power of the micro-organisms to decompose organic matter in the different soils and thus it is also in a way a measure of the general activity of the micro-organisms in the different soils.

Treatments given were as follows :—

Three lots of 100 gm of each of the soils were taken separately. Water equivalent to $\frac{1}{3}$ (one third) saturation capacity was added to all the three lots of the soil. To one lot of each soil no organic matter was added. To the second lot of each soil, oil-free ground nut cake equivalent to 7·5 mgm of nitrogen was added separately and to the third lot of each soil, oil-free ground-nut cake equivalent to 15 mgm nitrogen was added.

The amount of CO_2 formed in the soils used in the experiments was measured after every 24 hours. The experiment was conducted for 10 days and the total amount of CO_2 evolved in each lot of the four soils is given in Table No. 3.

TABLE No. 3

Mgm CO_2 per 100 gm soil

Soils	100 gm soil alone	100 gm soil+125 mgm cake	100 gm soil+250 mgm cake
Black cotton	147·14	199·71	225·24
Lateritic	199·72	254·98	358·79
Limestone	83·35	105·59	166·41
Granitic	90·24	186·07	184·04

Remarks on Table No. 3.—The results show that the organic matter in the limestone and granitic soils is less easily oxidized than in the other two soils, *viz.*, lateritic and black cotton soils when 125 mgm fresh organic matter is added to the soils the organisms in the three soils attack it except those in the limestone soil, the organisms in which are perhaps less active than those in the other soils. When 250 mgm of cake per 100 gm soils are added, however, the limestone soil catches up the black cotton and granitic soil which are less active than the lateritic soil. It shows that the lateritic soil probably will respond to a heavy dose of organic manure.

NITRIFICATION

This experiment is expected to indicate the capacity of the soil to make the nitrogen in the organic manure available to the crops.

Trearments given were as follows :—(1) 200 gm soil without any treatment. This was kept as control for comparing nitrification of the nitrogenous material originally present in the soil.

(2) 200 gm soil + 500 mgm oil-free ground-nut cake. 250 mgm cake was equivalent to 15 mgm of nitrogen for 100 gm soil.

TABLE No. 4 (a)

100 gm of Soil alone

Mgm N per 100 gm soil	Soils	I week	III weeks	V weeks	VIII weeks
As ammonia	Black cotton	0·12	3·36	3·56	3·96
	Lateritic	2·24	2·24	5·6	3·36
	Limestone	6·72	2·24	1·12	2·24
	Granitic	1·12	2·24	2·24	3·36
As nitrite	Black cotton	0·11	0·099	0·057	0· 11
	Lateritic	0·06	0·030	0·039	0·045
	Limestone	1·05	0·054	0·036	0·021
	Grantic	0·10	0·021	0·039	0·11
As nitrate	Black cotton	3·6	3·9	5·7	5·2
	Lateritic	0·9	2·4	3·0	2·4
	Limestone	2·1	2·1	1 ·8	3·3
	Granitic	0·9	1·35	1·8	1·2

TABLE No. 4 (b)

100 gm soil—Ground-nut cake equivalent to 15 mgm of N

Mgm N per 100 gm soil	Soils	I week	III weeks	V weeks	VIII weeks
As ammonia	Black cotton	1·12	2·24	2·24	3·36
	Lateritic	11·2	13·44	11· 2	13·44
	Limestone	6·72	3·36	2·24	1·12
	Granitic	4·48	4·48	4·48	8·96
As nitrite	Black cotton	0·96	0·06	0·066	0·20
	Lateritic	0·069	0·048	0·063	0·033
	Limestone	0·97	0· 39	0·069	0· 09
	Granitic	0·105	0·033	0·042	0·084
As nitrate	Black cotton	5·4	111·8	18·0	13·5
	Lateritic	1·8	1· 2	2·1	1·8
	Limestone	1·5	4· 5	7·8	10·8
	Granitic	1·2	1·35	1·2	0·9

Remarks.—The rate of nitrate formation in three soils black cotton, lateritie and granitic increased up to the 5th week and then went on decreasing but in the case of limestone soil there was an increase in nitrate up to the 8th week.

When the organic matter was added in the form of oil-free ground-nut cake the amount of nitrate formed in the black cotton and limestone soils increased to a great extent, while in the case of lateritic and granitic soils the amount of nitrate formed were found to have decreased. The reaction of the lateritic soils is slightly acidic, so it might have affected the nitrate formation in this soil.

In this experiment the granitic and lateritic soil did not show activity of nitrifying organisms. But after further experiments on additions of lime and nitryfying organisms to the lateritic and granitic soils and increasing the time of incubation from 8 week to 12 weeks, it was found that the lateritic soil require more time to nitrify the organic matter. There is no improvement, however, in the granitic soil showing that probably the conditions in this particular soil are suitable for the development of nitrifying organisms and so manuring this soil with nitrates is likely to be helpful to the crops grown in this soil, till such time as the conditions change and the nitrifying organisms begin to work normally in course of time.

Bacterial numbers.—The numbers of bacteria, which are micro-plants, present in the soil give information about the physical conditions prevailing in the soil for the growth of bacteria and also a general idea about the amount of soluble food material in the soil available to the bacteria and by inference for the growth of plants. The results obtained by plating the soils are given in Table No. 5.

TABLE No. 5

The number of organisms in the table are in lakhs per gram

Soils in	1	2	3	4	5	6	average
	Numbers counted on 3rd day						
Black cotton	40	36	28	38	44	46	38·66
Lateritie	46	44	34	30	40	34	38
Limestone	20	18	22	26	30	16	22
Granitic	34	26	30	36	28	29	30
	Numbers counted on 5th day						
Black cotton	52	48	44	46	50	48	48
Lateritic	50	40	42	52	40	52	46
Limestone	30	22	28	20	32	18	25
Granitic	36	26	40	30	42	42	36

Remarks on Table No. 5.—Numbers of bacteria are very nearly equal in the black cotton and lateritic soils and they are greater than those in the limestone soil. The number of organisms in the grantic soil is more than the number of organisms in the limestone soil but less than those in the black cotton and lateritic soils.

Pot culture experiments.—No manure was added to the soils and crops were grown in the soils as they were, the reason being as stated previously to see the effect of the activities of the micro-organisms on the decomposition of minerals existing in the soil and to see their natural crop-producing power for correlating it with minerals existing in the soil. Addition of organic manure would have prevented this as the decomposition of the added organic material occuring more readily than the decomposition of the soil minerals would have maked the effect of the decomposition of minerals by micro-organisms on the crop growth. The results are given in the following table :—

TABLE No. 6

Weight of dry yields in gms

Name of the soil	Pot No. 1	Pot No. 2	Pot No. 3	Pot No. 4	Average
		Wheat			
Black cotton	4·58	5·43	5·50	6·23	5·43
Lateritic	4·27	3·27	3·62	4·54	3·92
Limestone	3·81	3·72	4·20	2·80	3·63
Granitic	1·55	2·73	3·84	2·93	2·77
		Jowar			
Black cotton	5·40	4·78	3·60	5·34	4·78
Lateritic	3·50	2·70	4·80	3·00	3·50
Limestone	3·10	2·56	2·90	3·40	2·98
Granitic	2·40	2·48	2·70	2·02	2·40

Remarks on Table No 6.—The fertility of the black cotton soil as shown by its crop-producing power stands out clearly above all others and is the highest among the soils under investigation while the granitic soil stands last. The lateritic soil appears to be slightly more fertile than the limestone soil, but definitely less fertile than the black cotton soil.

CORRELATION

CO_2 evolution and heavy minerals.—Augite and iron ore are present in all the four soils used in our experiments and augite seems to be directly correlated with their respective quantities of CO_2 evolved. Iron ore does not appear to be correlated with CO_2 evolution. The minerals epidote, biotite and hornblende which are present in two soils only, are found to be directly correlated with the amount of CO_2 evolved in these two soils.

Nitrification and heavy minerals.—There does not exist any correlation (direct or inverse) between the nitrifying capacity of the soils and the percentage of augite in them. Percentage of minerals epidote, hornblende and biotite is inversely correlated with the nitrifying power of granitic and limestone soils. The nitrifying capacity of all these four soils is inversely correlated with their respective percentages of iron ore.

This conclusion appears to be correct because the greater the iron oxides and alumina in the soils, the less the calcium in the soils and unless sufficient calcium

in the form $CaCO_3$ is present in the soils for neutralization of nitrous and nitric acid produced during nitrification, the iron ore would be inversely correlated with the nitrifying power and hence addition of lime is indicated for securing good crops in the soils containing large amounts of iron ore, provided of course the soils are found to be sufficiently rich in the usual plant nutrients.

Bacterial numbers and heavy minerals.—Bacterial numbers of the lateritic and black cotton soils are inversely correlated with their respective percentage of the mineral augite. The percentage of the minerals epidote, hornblende and biotite which are present in two soils *viz* limestone and granitic soils are found to be directly correlated with the bacterial numbers of these two soils.

Fertility and heavy minerals.—Iron ore is directly correlated with the fertility of the limestone and laterite soils, but it is inversely correlated with the fertility of the black cotton and granitic soils. Percentage of augite increases the fertility of the lateritic soils as compared to the granitic and limestone soils.

Percentage of the minerals epidote, hornblende and biotite, present in limestone and granitic soils only, is inversely correlated to their corresponding crop-producing power.

This relation of iron and aluminium containing oxide and silicate minerals is found to be a bit puzzling. But propably these bases may themselves be really inversely correlated with fertility but the presence of other minerals containing calcium and magnesium silicates and that of $CaCO_3$ aggregates in the soils in sufficient quantity may be reversing the effects of oxides and silicates of iron and aluminium in altering the pH of the acidic soils containing iron and aluminium, just as the presence of calcium may be altering the pH of alkaline soils containing sodium. Thus we have probably to look to the presence of absence calcium minerals to see the effect of other minerals containing iron, aluminium or sodium being changed from what they would otherwise have been in the absence of calcium.

Fertility and CO_2 production.—The soils may be divided into two pairs, one pair having a high quantity of CO_2 evolved and the other having a comparatively low amount of CO_2 evolved, but the crop-producing power in both these pairs is inversely correlated with the amount of CO_2 evolved.

Fertility and nitrification.—The amounts of nitrates accumulated in the two soils, the black cotton soils and the granitic soil, both with and without the addition of the ground-nut cake, are directly correlated to their crop producing power. The quantity of nitrates accumulated under natural conditions that is without the addition of the ground-nut cake, in the laterite soil at the end of 12 weeks, is greater than the quantity of nitrates in the limestone soil at the end of the 8th week. These values are directly correlated with the respective crop-producing powers of these two soils.

With the addition of ground-nut cake to the two soils, however a greater amount of nitrates accumulates in the limestone soil than what is found in the lateritic soil. This indicates that the crop-producing power of the limestone soil will very probably be improved by the addition of organic manures.

Fertility and bacterial numbers.—There is a direct correlation between the crop yields and the numbers of bacteria in the black cotton soil and the lateritic soil, but in the two other soils, *viz.*, the granitic and the limestone soils, the bacterial numbers seems to be inversely correlated to their respective crop-producing

power, probably the presence of a greater amount of lime in the limestone soil is helpful in overcoming the effect of the lower numbers of bacteria in the limestone soil.

General conclusions —In trying to find the existence of correlations between the different factors of the four soils we have seen that frequently the soils were divided into two groups according to the nature of correlation that is direct or inverse, because there happened to be a similarity in one character but a difference in other. This resulted in a reversal of the expected correlation. One character that caused such reversal of correlation happened to be the presence of lime in the soils which is one of the major plant nutrients. Perhaps other major plant nutrients may also cause reversal of the expected correlation. So in calculating and predicting the crop-producing powers of soils from the results of examinaion of one or two singls factors of soils, such influences are bound to change the effect of and one factor and cannot be neglected.

So far as we know this is the first time that such an attempt to seek correlation among the mineral composition of the soils on the one hand and micro-biological activities and crop-producing powers of the soils on the other has been made. Hence it is not possible for us to refer to or compare our results and conclusion with those of any previous investigation, as no such experiments were ever undertaken by any also be taken as axiomatic truths.

In order to get some clear idea about the correlation and establish them on a sound footing by excluding outside influences such as the presence of major plant nutrients, as mentioned above, it will be necessary to examine a large number of soils and see what correlations exist among the factors studied by us *viz.*, mineral composition, macrobial activities and crop-producing power of the different soils. We expect that such an enquiry will doubtless lead to some useful results.

REFERENCES

1. Robinson, G. W., 1934, See "*Soil Analysis*" by C. H. Wright, London, pp. 33—37.

2. Wright, C. H., 1934. "*Soil Analysis*" London, p. 11.

3. Collins, S. H., 1908. *Jour. Soc Chem. Ind.*, **25**, pp. 518—522.

4. Keen, B. A. and Coutts, J. R. H. 1928 *Jour. Agric. Sci.* **18**, pp. 740—765.

5. Holmes Aurther, 1920. "*Petrographic Methods*" *Reprinted* (1935) pp. 66–70.

6. Ross and Kerr, 1931. *U. S. Goel. Survey Professional Paper No.* 165—*e*. .

AFTER EFFECTS OF PHOSPHATE MANURED BERSEEM ON WHEAT

By

S. S. SINGH

Agricultural Liason Officer, Development Commissioner's Office, Rewa

and

S. SEN

Indian Agricultural Research Institute, New Delhi

(Received on 11th October, 1954)

INTRODUCTION

Of all the methods the simplest and cheapest way for building up of soil fertility is use of legumes It has been recognised long back that to function effectively, nodule bacteria require phosphates, besides elements like calcium and molybdenum. In the present investigations attempts have been made to assess the fertility built up by phosphate manuring of berseem as reflected by growth and yield of wheat.

REVIEW OF LITERATURE

Extensive work has been done on the phosphate manuring of legumes in building up of soil fertility. Investigations are also in progress at the I.A.R.I. and very conclusive results have been attained here.

Parr in 1946 after experimenting on phosphate manuring of legumes concluded that manuring with P gives higher yield of fodder and builds up stable soil fertility. Berseem manured with P was followed by unmanured wheat for three continuous years and the yields were higher than the control. He also showed that the increasing dose of phosphates particularly super increased the yield of berseem and of unmanured wheat following it. While describing the role of phosphates in mixed farming he said that by stimulating the growth of legumes, P stimulated nitrogen fixation in the soil and so builds up soil fertility.

Parr and Bose in 1947 observed that high doses of super increased the yield of berseem and built up residual value for the next crop. Parr and Sen in 1948 concluded that for soils low in P, green manuring is effective only when adequate amounts of P are added to the legume.

Venkat Rao and Govindrajan (1951) studied the affects of application of phosphate to green manures and found that there were not only increase in the yield and nitrogen content of green manures but also increase in the yield of paddy and ragi following them.

Govindrajan in 1951 said that the effectiveness of phosphates to a cereal crop is enhanced when phosphate fertilizers are applied to leguminous crops which are grown and used as green manure to the succeeding cereal crop.

MATERIALS AND METHODS

The manure was applied in the form of farmyard manure, super-phosphate and mixtures of both. The results of the experiments conducted during the year 1951-52 are given when the first unmanured wheat crop was grown after three manured crops of berseem. The rotation followed was (*i*) Berseem-fallow-wheat, and (*ii*) Berseem-cowpea-wheat. The manurial treatments per acre per year applied to berseem were as follows :—(A) 16 lbs P_2O_5 as FYM ; (B) 32 lbs P_2O_5 as FYM ; (C) 64 lbs P_2O_5 as FYM ; (D) 16 lbs P_2O_5 as super-phosphate ; (E) 32 lbs P_2O_5 as super-phosphate ; (F) 64 lbs P_2O_5 as super-phosphate ; (G) 8 lbs P_2O_5 as super-phosphate + 8 lbs P_2O_5 as FYM ; (H) 8 lbs P_2O_5 as super phosphate + 24 lbs P_2O_5 as FYM ; (I)—8 lbs P_2O_5 as super-phosphate + 56 lbs P_2O_5 as FYM ; (J) 8 lbs P_2O_5 as FYM + 24 lbs P_2O_5 as super-phosphate ; (K) 8 lbs P_2O_5 as FYM + 56 lbs P_2O_5 as super-phosphate ; (L) Berseem without manure ; (M) No berseem and no manure *i.e.*, fallow for berseem season. Treatments A, B and C, D, E and F, G, H and I and J and K form four different forms of manures namely, FYM, super., Mix. I and Mix. II, respectively.

LAYOUT AND REPLICATIONS

Split plot design with three replications.
Size of the plot—60′ × 12′ or 1/60·5 of an acre
Nitrogen in soil was determined by modified Kjeldhal—Cunning method.

In Tables No. 2, 6 and 10, SEm_2 refers to Mix. II ; and similarly in Tables No. 3, 7 11 and it refers to 16 lb. P_2O_5.

EXPERIMENTAL FINDINGS

TABLE No. I

The average of the final heights attained by plants under different treatments

Treatments	A	B	C	D	E	F	G	H	I	J	K	L	M
Height in cm	79·0	83·51	86·21	80·23	85·33	93·21	77·06	83·45	86·48	81·71	90·6	75·58	74·61

Order

F K I C E B H J D A G L M

SEm. ± 1·78 C.D. at 5% 4·93 at 1% 6·47

Plant under treatment F attained significantly better height than those under all others treatments except K which too leaving treatments I and C indicated significantly better height in the plants than rest of the treatments. There was no significant difference in the heights of the plants grown under the treatments I, C, E, B, H and J, but plants under treatments I and C were significantly better in height than those grown under the treatments beyond J in order of merit. Treatment E was significantly better than all after D, while treatments B and H were significantly superior to all after A arranged in descending order. There was no significant difference between treatments J, D, A and G, but treatment J was significantly better than treatments L and M while treatment D showed its superiority significantly over M. There was no significant difference between treatments A, G, L and M.

TABLE No. 2

Effect of different forms of manures on the height of the plants

Forms	Super	Mix. II		FYM	Mix. I
Average height (cms)	86·26	86·15		82·91	82·83 at 5%
				5%	1%
SEm_1		±1·026	CD_1	2·844	3·738
SEm_2		±2·257	CD_2	3·181	4·180

Manure in the form of super-phosphate and Mix. II was significantly superior to FYM and Mix. I in inducing greater heights in plants. There was no significant difference between farmyard manure and Mix. I.

TABLE No. 3

Effect of doses on the height of plants

Doses		64 lbs		32 lbs	16 lbs
Average height (cms)		89·13		83·50	78·76 at 1%
				5%	1%
SEm_1	±0·89		CD_1	2·462	3·237
SEm_2	±1·07		CD_2	2·661	3·498

Plants grown under 64 lbs dose were significantly greater in height than those under 32 lbs ; which in turn were significantly greater in height than those grown under 16 lbs doze.

TABLE No. 4

Effect of rotation on the height of plants

Rotations	Fallow	Cowpeas
Average height (cms)	83·19	82·22
SEm	±1·01	Not significant

NUMBER OF TILLERS

TABLE No. 5

The average number of tillers under different treatments

Treatments	A	B	C	D	E	F	G	H	I	J	K	L	M
	4·03	4·26	4·40	3·86	4·25	5·06	3·91	3·86	4·26	4·99	4·86	3 23	2·86
Order at 5%	F	K	C	I	B	E	A	J	G	H	D	L	M

SEm ±0·32 CD at 5% 0·881 CD at 1% 1·173

There was no significant difference between the number of tillers under the treatments F, K, C, L, B and E, but F was significantly better than all the rest of the treatments mentioned after E, while K was significantly superior to all after J

in order of merit. Treatments C, I, B and E were significantly better than the treatments L and M. All the treatments were significantly better than treatments M except L which was also better but not significantly.

TABLE No. 6

Effect of different forms of manure on the number of tillers

Forms	Mix II	Super	FYM	Mix. I
Average number	4·43	4·39	4·23	4·01

SEm_1 ±0·19 SEm_2 ±0·23

There was no significant difference in the number of tillers observed under different forms of manure.

TABLE No. 7

Effect of doses on the number of tillers

Doses	64 lbs	32 lbs	16 lbs	
Average number	4·65	4·09	3·94	at 5%
SEm_1 ± 0·16	S. Em_2 ± 0·19	CD_1 at 5%	0.446	at 1% 0·586
		CD_2	0·482	0·636

There was no significant difference between 32 lbs and 16 lbs dose but 64 lbs significantly increased the number of tillers over 32 lbs and 16 lbs dose.

TABLE No. 8

Effect of rotation on tiller number

Rotations	Fallow	Cowpeas
Average number	4·10	4·03

SEm ± 0·11

There was no significant difference in the number of tillers under different rotations.

YIELD STUDIES

TABLE No. 9

Grain yield

Average yield of grain in mds per acre under different treatments

Treatments.	A	B	C	D	E	F	G	H	I	J	K	L	M
Mnds mds/ acre	13·88	16·00	18·54	14·05	16·86	20·94	16·12	16·30	18·51	17·75	21·06	12·13	0 33

Order at 5%	K	F	C	I	J	E	H	G	B	D	A	L	M

SEm ± 1·20 CD at 5% 3·33 at 1% 4·37

There was no significant difference between the yields of grain under treatments K, F, C, I and J but treatments K and F were significantly better than the

rest; while no significant difference was observed between treatments from C to B arranged in the descending order of merit. Treatments C, I and J were significantly better than treatments D, A, L and M. Treatments D, A and L did not show any significant difference among themselves. All the treatments except L were significantly better than treatment M.

TABLE No. 10

Effect of different forms of manure on the grain yield

Forms	Mix. II	Super	Mix. I	FYM.
Average yields mds/acres	19·36	17·24	16·94	16·26 at 5%

$SEm_1 \pm 0·69$	$SEm_2 \pm 0·85$	CD_1 at 5%	1·921	at 1%	2·524
		CD_2	2·148		2·823

Grain yield produced with Mix. II was significantly higher than those produced with Mix. I and FYM. There was no significant difference between the yields with Mix. II and super. Yields with super. Mix. I and FYM also did not show any significant difference.

TABLE No. 11

Effect of doses of manure on the grain yield

Doses	64 lbs	32 lbs	16 lbs
Average yield	19·73	16·80	14·64 at 1%
$SEm_1 \pm 0·60$	CD_1 at 5%	1·663	at 1% 2·187
$SEm_2 \pm 0·69$	CD_2	1·798	2·362

64 lbs dose increased the yield significantly over 32 lbs and 16 lbs; 32 lbs dose also produced significantly higher yield than 16 lbs dose.

TABLE No. 12

Effect of rotation on the grain yield

Rotations	Fallow	Cowpea
Average yield (mds/acre)	16·70	15·91 SEm $\pm$ 0·11
	CD at 5% 0·298	at 1% 0·391

Yield of grain obtained under the rotation having fallow was significantly more than obtained under the rotations having cowpeas instead of fallow.

Percentage of Nitrogen in the Soil.

Percentage of total nitrogen in the soil as influnced by different treatments

Treatments	A	B	C	D	E	F	G
Percentage of N	0·05005	0·05070	0·05090	0·04635	0·04935	0·05035	0·04600
	H	I	J	K	L	M	
	0·04815	0·05010	0·04880	0·05045	0·04340	0·04200	

The above data show that the highest percentage of nitrogen was found in the plots under treatment C, B and F and lowest under treatment M. Treatment L left more nitrogen in the soil than treatment M. It is clear from the data that all the plots with treatments having berseem in the previous season left more nitrogen in the soil than no berseem treatment, and all the treatments with manure showed higher percentage of nitrogen in the soil than no manure treatment.

TABLE No. 14

Effect of forms of manures on the nitrogen percentage in the soil

Forms	FYM	Mix. II	Super	Mix. I	No manure
Percentage of N	0·05055	0·04962	0·04868	0·04808	0·0427

The above data show that phosphate applied in different forms had little effect on the percentage of nitrogen in the soil.

TABLE No. 15

Effect of doses of manures on the nitrogen percentage in the soil

Doses	64 lbs	32 lbs	16 lbs
Percentage of N	0·06726	0·06566	0·04746

The above data show that higher doses of phosphate left higher percentage of nitrogen in the soil. The highest percentage was found under 64 lbs dose of P_2O_5 and lowest under 16 lbs dose. 32 lbs dose showed higher percentage of nitrogen them 16 lbs but lower than 64 lbs dose.

TABLE No. 16

Effect of rotations on the nitrogen percentage in the soil

Rotations	Fallow	Cowpeas
Percentage of N	0·04933	0·04706

It is obvious from the above data that keeping fallow in the rotation maintained a higher percentage of nitrogen in the soil than growing cowpeas which left a lower percentage of nitrogen in the soil for the crop to follow.

REFERENCES

1. Govindrajan, S. V., 1951, More effective use of fertilizers. *Mysore Agri. Jour.*, **26**, 57-58.

2. Parr, C. H., 1946. Phosphate manuring of Legume. *Sci. Report Ind. Agri. Res. Inst.*, 23-25.

3. Parr, C. H. and Bose, R. D., 1947. The role of phosphate in mixed farming. *Ind. Farming*, **8**, 512-16.

4. Parr, C. H. and Sen, S., 1948. Phosphate manuring of legumes in relation to green manuring. *Ind. Farming*, **9**, 227– 233.

5. Venkat Rao, B. V. and Govindrajan, S. V., 1951, Phosphate manuring of legumes, its influence on nitrogen fixation and on the yield of succeeding crop of cereals. *Proc. 39th Ind. Sci. Congress*, Part III, 300.

EFFECT OF FERTILIZERS ON YIELD OF *CORIANDRUM SATIVUM* (*DHANIA*)

By

S. S. SINGH

Agricultural Liason Officer, Development Commissioner's Office, Rewa.

(Received on 1st October, 1954).

Among all the spice crops *Coriandrum sativum* is one of the most important. On a commercial scale it is mostly grown in Bombay and Madras Presidencies and in Central India and in a very scattered way in Uttar Pradesh also. Very little work has been done towards increasing the yield in this crop by supplying its optimum requirements. Investigations were started on this crop in the year 1943-49 at this Institution when the germination and biology of flowering were worked out.[1] As some information on its manurial requirements was necessary to conduct field experiments to draw up a cultural and manurial schedule for this crop, the effect of nitrogen, phosphorus and potash singly and in combination on the growth, development and yield of the plant was studied in pot culture during 1949-50. The present note deals with the yield of the plant as influenced by these treatments.

Experimentation.—The experiment was conducted in pot (10″ × 12″) using sound seedings of the local type which are maintained here in a pure form. The soil used for the purpose was from 6″ below the surface soil to see the clear response of the fertilizers. Effects of nitrogen, phosphorus and potash singly and in combination were studied; these were added in the form of ammonium sulphate (20% N), super-phosphate (18% P_2O_5) and kainite (12·5% K_2O) respectively at the rates of 60 lbs of N, 40 lbs P_2O_5 and 20 lbs K_2O per acre. There were 8 treatments in all *viz.*, N, P, K, NP, PK, NK and NPK and control and each one was replicated 15 times. Yield was measured in terms of the number and weight of fruits per plant.

Number of fruits per plant.—The number of fruits produced per plant was significantly greater in the nitrogen treated plants, while in potash treated plants it was significantly depressed as shown in the following table :—

TABLE No. 1 (*a*)

Treatments	Average No.	C. D. at	
No	17·65	1%	4·99
N	44·00	5%	3·78
Ko	34·60	1%	4·99
K	27·06	5%	3·78

Both the interactions NP and NK had also significant effects on the number of fruits produced, the former in increasing the number while the latter in reducing the number as shown in the following tables :—

TABLE No. 1 (*b*)

Treatments	No	N	C. D.	
Po	18·63	42·21	1%	7·06
P	16·63	45·80	5%	4·34

Application of P had no significant effect over no application of P under No and N treatments but application of N had significant effect over No under both Po and P treatments.

TABLE No. 1 (*c*)

Treatments	No	N	C. D.	
Ko	19·53	49·66	1%	7·06
K	15·76	38·35	5%	5·34

Application of K had not significant effect over no but under N treatment it significantly (1%) depressed the number of fruits. Addition of N significantly increased the number of fruits under Ko and K treatments. The highest number of fruits was found under NKo treatment (49·66) and the least was noted under NoK (15·76).

Weight of fruits per plant.—Application of N and P had significantly beneficial effects on the weight of fruits while the addition of K had significantly detrimental effect on the weight of fruits as is evident from the following tables :—

TABLE No. 2 (*a*)

	Treatment	Average weight in gms	C. D.	
(*a*)	No	0·075	1%	0·007
	N	1·190	5%	0·005
(*b*)	Po	0·126	1%	0·007
	P	0·134	5%	0·005
(*c*)	Ko	0·148	1%	0·007
	K	0·115	5%	0·005

Effect of interaction between N and K on the weight of fruits is shown below :—

TABTE No. 2 (*b*)

Treatment	No	N	C. D.	
Ko	0·08	0·21	1%	0·013
K	0·06	0·16	5%	0·009

Application of N both in presence and absence of K significantly increased the yield while addition of K significantly reduced the yield under both the treatments. On the whole NKo treatment gave the highest yield (0·21 gms) and the lowest yield was observed under NoK (0·03 gms).

The coriander plant has as is evident from the above data shown varying responses to the three major plant nutrients N, P and K. Response to N has been towards better yield while that to K has been towards depression, P had a slight beneficial effect.

N significantly increased the number of fruits by 149·3 %, while K depressed the number of fruits per plant by 21·2%. Detailed studies on flowering have indicated that this effect of N on the number of fruits was brought about by a significant increase in the total number of umbels per plant and number of umbellets in primary and secondary umbels ; the effect of potash in all these cases was towards lowering the numbers.

The weight of fruits per plant was significantly increased under N by 153·3% and significantly depressed under K by 22·3%. The increased weight of fruits per plant under N has been brought about by an increase in the number of fruits per plant.

The results of the present work indicate that coriander also shows marked favourable response to nitrogen application like many other crops yielding foliage and fruits as economic products and that yields in this crop may be increased very appreciably by suitably fertilizing the crop.

The author has pleasure in expressing his thanks to Dr. N. K. Anant Rao, Professor of Agronomy, Balwant Rajput College, Agra under whom this work was conducted.

REFERENCE

1. Paliwal, R. L., *Thesis for M. Sc. Ag. (Bot.) Agra University*, 1949.

EFFECT OF ORGANIC AND INORGANIC MANURES ON THE GROWTH AND YIELD OF WHEAT

By

S. S. SINGH

Agricultural Liason Officer, Development Commissioner's Office Rewa

(Received on 1st October, 1954)

INTRODUCTION

The soil is chief medium on which agriculture operates. As such its composition, fertility and its conservation are of highest importance. Soil fertility depends upon many complex factors, but actually speaking the main problem of today in maintaining soil fertility is to ensure the supply of essential plant food and organic matter under optimum moisture condition. In India fertility is largely synonymous with the presence of adequate supplies of nitrogen in organic as well as inorganic forms. High fertility of the soil is a desirable condition resulting from the complete harmony among all the different growth factors. With this object in view, the present investigation on "Building up of soil fertility by organic and inorgonic manures" has been taken up to assess the fertility building capacity of organic and inorganic manures as reflected by the growth and yield of crops in the rotation, wheat—maize—wheat.

Lander (1937) concluded that the organic manures (FYM and compost) produce definite effects, and in case of heavy doses, it is significant even after harvesting three crops.

Vishwanath (1937) reviewed that the greatest returns are generally obtained by nitrogenous manuring, although the action of phosphates is considerable and in many instances combination of nitrogen and phosphates has given higher yield than nitrogen alone.

Mukerji and Agarwal in 1950 reviewed that increased yields of paddy as a result of green manuring have been reported from many provinces. The increase in the yield of cane as a result of green manuring has been estimated at about 50% over unmanured canes. Green manuring of wheat is considered feasible only in tracts where surfficient autumn rains are available or irrigation facilities exist. In the Punjab, the beneficial effects of green manure seem to last for four to five years, but at Pusa, *sunn* as a main source of nitrogen appeared insufficient in a two year four course rotation.

The experiments as Patel described in 1937 clearly show the beneficial effects of green manuring as compared with FYM.

Rege in 1941 said that a smaller tonnage of millable canes is invariably obtained with the same quantity of nitrogen if applied all in the form of FYM as

compared to either oil-cake or sulphate of ammonia or their mixture with FYM. The relative availability of nitrogen from farmyard manure is lesser than those of cakes and sulphate of ammonia.

Panigrahi in 1950 found that the green manure treatment showed its superiority over other manures in producing highest grain yield of wheat. Treatments N, PK, N, P and P were significantly superior to control in the out turn of grain per acre. He observed that potash in combination with nitrogen and phosphate had beneficial effect on crop yield. Combination of manures and fertilizers produced higher yield of grain and straw in comparison with manures and fertilizers separately though the interactions were not significant.

MATERIALS AND METHOD

The experiment was conducted during the *rabi* season of 1952-53 at the I.A.R.I. Farm (Mid. Block C_1 and C_2), New Delhi. The treatments were as follows :—

Main plot treatments.— A.—No organic manure.
B.—Green manure with guar.
C.—Castor cake at the rate of 60lb N/acre.
D.—FYM @ 60 lbs. N/acre.

Sub-Plot treatments.—1. No inorganic fertilizers ;
2. $(NH_4)_2SO_4$ @ 40 lb N/acre ;
3. Super-phosphate @ 80lb P_2O_5/acre ;
4. $(NH_4)_2SO_4$ + super. @ 80 lb. P_2O_5/acre.
5. $(NH_4)_2SO_4$ super + K_2SO_4 @ 60lb K_2O/acre.

The layout was of split plot design with six replications ; total number of plots being 120. The net plot size was 48′ x 21′—1/43·21 acre. Wheat was sowl at the rate of one maund per acre with variety NP.—760. Total average annuan rainfall is 25″. The crop was grown on irrigation.

EXPRIMENTAL FINDINGS AND DISCUSSIONS

Height of the plants.—Average height of plants in cms as influenced by different treatments.

TABLE No. 1

Treatments	A (control)	B (G. M)	C (C. Cake)	D (FYM)	Total	Average
1. Control	108·5	107·1	103·9	107·2	426·7	106·7
2. $(NH_4)_2SO_4$	118·1	127·2	116·7	116·8	478·8	119·7
3. Super	108·4	114·2	108·8	108·2	439·6	109·9
4. N+P	114·9	127·5	116·8	113·5	468·7	114·7
5. N+P+K	120·1	123·3	116·4	114·6	474·4	118·8
Total	570·0	599·3	562·6	560·3		
Average	114·0	119·8	112·5	112·0		

	S.E_m	C.D. 5%	C.D. 1%	
M. P. treatment	±4·06			Not significant
S. P. treatment	±2·83	8·48	11·86	
Interaction	±5·67			Not significant

order—	2	5	4	3	1	
	119·7	118·8	114·9	109·9	106·7	at 5%

The above table indicates that the plants under treatment B attained better height than those under treatments A, C and D. It shows that green manuring induces better height in plants than other organic manures.

Among the inorganic fertilizers, treatment 2 induced the greatest height in plants followed by treatments 5, 4, 3 and 1 in order of merit. Treatments 2 and 5 were significantly better than treatments 3 and 1. It shows that application of nitrogen is beneficial to plant growth. Application of phosphate and potash did not show any effect on the height of plants. The interaction between organic and inorganic manures did not show any significant effect, though by studying the table it is clear that organic manures when supplemented with inorganic nitrogen give better results.

Average number of tillers per plant under different treatments

TABLE No. 2

Treatments	A (control)	B (GM)	C (C Cake)	D (FYM)	Total	Average
1. Control	3·0	3·2	2·6	2·6	11·4	2·8
2. $(NH_4)_2SO_4$	3·3	3·3	3·1	3·1	12·8	3·2
3. Super	2·6	3·5	2·8	3·1	12·0	3·0
4. N+P	3·3	3·6	3·2	3·1	13·2	3·3
5. N+P+K	3·1	3·6	3·5	3·1	13·3	3·3
Total	15·3	17·2	16·2	15·0		
Average	3·0	3·4	3·2	3·0		

SEm— MP treatments— ±·134
S.P. ,, ±·168 Not significant.
Interaction ±·336

The above shows that the number of tillers produced was more under all the manurial (inorganic) treatments as compared to those produced under no manure treatments. Nitrogenous manures produced greater number of tillers than those without nitrogen, though the differences were not significant. Among the organic manures, green manuring produced greater number of tillers followed by castor cake. There was no difference between the treatments A and D. There was no significant difference among the treatment effects on the number of tillers per plant.

Yield studies.—(*Grain yield*). Average yield of grain in lb per plot under different treatments.

TABLE No. 3.

Treatments	A control	B GM	C C Cake	D FYM	Total	Average	Md/acre
1. Control	26·7	32·4	29·5	25·6	114·2	28·5	14·96
2. $(NH_4)_2SO_4$	34·4	36·8	37·0	34·0	142·2	34·5	18·64
3. Super	23·0	35·0	31·5	26·3	116·3	29·0	15·23
4. N+P	36·6	37·7	33·9	33·6	141·8	35·4	18·58
5. N+P+K	32·2	38·6	36·5	34·2	141·5	35·4	18·58
Total	152·9	181·0	168·4	153·7			
Average	30·6	36·2	33·7	30·7			
Md/acre	16·06	19·00	17·69	16·11			

	SEm	CD 5%	CD 1%	
M. P. treatments.—	±1·416	4·26	5·89	
	(·743)	(3·23)	(3·09)	md/acre
S. P. treatments	±·697	1·93	2·53	
	(·365)	(1·01)	(1·33)	md/acre
Interaction	±1·395			
	(·730)			Not significant.

B	C	D	A	
36·2	33·7	30·7	30·6	@ 5%

2	4	5	3	1	
35·5	35·4	35·4	29·0	28·3	@ 5%

It is evident from the above table that the highest yield of grain was produced under treatment C, among the organic manure treatments, followed by treatments C, D. A in order of merit. Treatment B gave significantly higher yield than treatment A. No significant difference was observed among the yields obtained under the treatments C, D and A.

This difference in yield is attributed to the fact that number and weight of grains per ear-head and number of ear-bearing tillers were affected by the organic manures in the same order. Studying the effects of inorganic manures it is observed that all the nitrogenous treatments yielded significantly better results than no nitrogen treatment. No significant difference was seen among the treatments 2, 4 and 5 which indicates that it is only nitrogen, responsible for higher yields and no P or K whether alone or in combination. The increased productions under treatments 2,4 and 5 is due to the presence of nitrogen which had produced greater number and weight of grains per ear-head along with the greater number of ear-bearing tillers.

Though the effect of the interaction between organic and inorganic manures was not significant, a critical study of the table shows that organic manures in the presence of inorganic fertilizers produced better grain yields. This effect is especially noticeable with the inorganic nitrogenous fertilizers.

ACKNOWLEDGMENT

The author takes this opportunity of expressing his thanks to Dr. T. J. Mirchandani, Head of the Division of Agronomy, I.A.R.I., New Delhi, under whose guidance the work was carried out

REFERENCES

1. Lander, P. E., (1937), A short note on the manurial experiment in Punjab. *Proc. Bd. Agric. and Ani. Husb. Crops and Soils Wing, 2nd Meeting* : 182.
2. Mukerji, B. K. and Agrawal, R. R., (1950), Review of green manuring practices in India., *Misc. Bull. I.C.A.R.* : 68.
3. Panigrahi, P.K. (1951) Effect of organic manures alone and in combination with inorganic fertilizers on soil fertility. Thesis submitted for part fulfilment for *Assoc. I.A.R.I., New Delhi.*
4. Patel, B. S. (1927), Green manuring for the black cotton soils of Surat tracts of Bombay Presidency., *Proc. Bd Agric. and Ani. Husb. Crops and Soils Wing, 2nd Meeting* : 191.
5. Rege, R. D. (1941), Fertilizer experiments on sugarcane in India., *Misc. Bull. I. C. A. R.* : 41.
6. Vishwanath, B. (1937), Notes on subject II (A review of theory and practices of manuring in India)., *Proc. Bd. Agric. and Ani. Husb. Crops. and Soils Wing, 2nd Meeting* : 167.

JUTE AND SOIL FERTILITY

Part I—Nitrogen Problem

By

M. K. MUKHERJEF, S. C. CHAKRAVORTY, A. K. KUNDU, *and* G. HALDER

Jute Agricultural Research Institute, Barrackpore, West Bengal

(Received on 30th November, 1954)

INTRODUCTION

The jute fibre of commerce is obtained from the bark of the plant. The fibre constitutes only 5 to 6 % by weight of the plants at the harvest. At the harvest 16000 to 20000 lbs of green matter is usually produced from an acre of land and 40000 lbs of green matter is also not a rare phenomenon. This is much more than what is produced per acre in case of cereals. When the production of green matter is such a large quantity, the withdrawal of plant nutrient from the soil is also considerable. The vegetative phase of the plant is most important from the point of view of fibre production as the yield of fibre is proportional to the height and base diameter of the plant (Patel and Ghosh, 1945 ; Kundu, 1953, 1954*a*, 1954*b*).

Of the various major plant nutrients, nitrogen affects the vegetative growth most. Depending on several factors, the quantity of nitrogen withdrawal by the plants during their growth varies from 100 to 250 lb per. acre (Kundu, 1953 ; Kundu and Mukherjee, 1953*a*, 1953*b* ; Kundu and Chakraborty, 1944). The question therefore, naturally arises how to supplant this enormous quantity of nitrogen to the soil. More so, when the trend is to get an additional food crop from jute lands and/or to grow jute in aman paddy lands, particularly in places where the rainfall is favourable or irrigation facilities are available. To this, it must be added that particularly in view of paucity of rettting water in many places in Indian Union, the present policy is to attempt an increase in the yield per acre in areas where retting facilities are better. All out attempts are, therefore, being made to produce more jute, better jute and cheaper jute. Manuring with nitrogenous fertilizers has been found to be paying. Experiments carried out by this Institute in its own farms and in the cultivators plots spread over different jute growing states have shown that at lower doses of nitrogen (20 to 40 lb N per acre) usually one pound of nitrogen can increase the fibre yield by seven to twelve pounds. Depending on soil conditions, responses of similar nature have been found even at higher doses of nitrogen (100 lb or more of N per acre). Of the various inorganic fertilizers used, ammonium sulphate and sodium nitrate have been found to be the best (Kundu, 1954*a* ; Mukerjee, *et al*, 1954*a*). Jute responds also to various organic manures. The increase in the yield of fibre by the application of ammonium sulphate under the present day conditions makes the use of fertilizers a paying proposition to the cultivator (Kundu, 1954*c*). The problem, therefore, is whether cultivation of jute should be encouraged at all in Indian soils which are known to be highly deficient in nitrogen as successful jute crop

in an area of more than million acres (1953 acreage—1·3 million) would require all the nirogeneous fertilizers available in the country. The question is as old as jute cultivation. The question was raised in the enquiry on the cultivation of a trade in jute in Bengal and on fibres carried out by Mr. Hem Chunder Kerr in 1872-73. In his report submitted in 1874, he has mentioned that there is unanimity in the point that for growing jute, as much manure available should be used but there are divergent opinions on the soil fertility status due to growing of jute. Collectors of some districts are of opinion that jute exhaust the soil so much so that jute should not be grown in the same land year after year. Collectors of some other districts, many zemindars and some jute merchants on the contrary hold the view that the leaves of jute plant which fall off and rot serve as a manure to enrich the soil. Collector of Jalpaiguri district mentioned that the fertility status of soil increases almost on the number of years jute has grown on it. Kundu (1934*a*), Kundu and Mukherjee (1953*a*, 1953*b*), Mukherjee *et al* (1954*a*, 1954*c*) state that due to the cultivation of jute as a preceding crop, the yield of aman (winter) paddy is not suppressed provided the date of transplantation be same. Naithani (1954) states that in the reclaimed lands of Uttar Pradesh, wheat grows better in lands where jute has been grown as a preceeding crop than in lands which remained even fallow before wheat. Collector of Purnea (Kerr, 1874) in his report as old as 1873 states that after a crop of jute, mustard grows better. Sub-divisional Officer, Baraset and Babu Jaykissen Mukherjee, zemindar of Uttarpara in the district of Hoogly, (Kerr, *ibid.*) also in the same year state that a subsequent crop of paddy after jute is usually better. In our recent enquiry in the Barrackpore, Baraset and Basirhat sub-divisions of 24 Parganas district, the majority of the cultivators hold the view that after a crop of jute, paddy yield is usually better.

Leaf fall in jute has been ascribed by several persons to be the main reason for the improvement of soil fertility. During the growth of the plant, considerable number of leaves fall. The following table shows the extent of leaf fall per plant. The data have been obtained by taking records from 18 plants selected at random in each plot of a varietal-*cum*-manurial trial carried out in 1953 jute season having 4 varieties, two doses of manuring (unmanured and manured with 50 lb nitrogen per acre) with three replications. Varieties taken are the two improved strains evolved by this Institute, *C. olitorius* 040—632 and *C. capsularis* C-39—212 and two standard strains, *olitorious-C. G.* and *capsulari* D-154.

TABLE No. I

The extent of leaf fall in Jute

	Number of leaves per plant in							
	O-632		CG		C-212		D-154	
	*†M	U	M	U	M	U	M	U
Leaves fallen	43	43	41	43	45	39	40	37
Leaves expected to fall at harvest	5	5	12	6	12	13	14	17
Leaves in the stem not expected to fall at harvest stage	21	21	45	32	94	71	60	69
Leaves in the tip not expected to fall at harvest stage	8	6	19	10	24	23	20	19

	Green weight of leaves per plant							
	O-632		CG		C-212		D-254	
	†*M	U	M	U	M	U	M	U
Leaves fallen	41	40	40	41	33	30	30	29
Leaves expected to fall at harvest	3·5	3·8	5·5	3·3	7 2	6·5	8·6	8·5
Leaves in the stem not expected to fall at harvest stage	9·1	9·8	15·0	11·4	20·9	14·0	15·3	15·3
Leaves in the tip not expected to fall at harvest stage	0·7	0·9	2·4	1·1	1·4	1·4	1·9	1·7

*M—Ammonium sulphate equivalent to 50 lb N per acre.
†U—No manure.

The dry weight of leaves containing 3—5 % nitrogen falling per acre often amounts to more than 2000 lb. If the quantity of nitrogen returned by the leaves be considered, the amount of withdrawal by a crop of jute amounts to 80—130 lb nitrogen (Kundu, 1953, Kundu and Mukherjee, 1953-*a*, 1953-*b*, Kundu and Chakravorty, 19 4). This is similar to the observation of Connell, (1942) in case of fibre flax in New Zealand. Even then, it was considered that a thorough study of nitrogen status of soils due to cropping with jute should be undertaken.

METHODS, RESULTS AND DISCUSSION

Soil samples were taken from at least five places in each plot at 0″—6″ depth and were thoroughly mixed. 100 gm portions of the samples were taken immediately after mixing for determination of ammonia nitrogen and nitrate nitrogen by Richardson's, (1938) modification of Olsen's (1929) method. Simultaneously another 20 gm portion was taken for determination of moisture. Results of ammonia nitrogen and nitrate nitrogen determination are expressed on oven-dry basis. Rest of the samples were dried in air by spreading in thin layers on enamelled dishes. The soils were then powdered to pass through a 2mm seive. 14 gm portions were then taken for determination of total nitrogen by Bal's (1925) modification of standard digestion method. Simultaneously another 20 gm portion was taken for determination of moisture. Results of total nitrogen are also expressed in oven-dry basis.

The treatmentwise data for 1950 and 1951 season, when the experiment were carried out at Chinsurah farm are summarised in Table No. II. There were 4 replications in randomized block layout.

TABLE No. II

Percentage total nitrogen before and after jute harvested at different stages of growth

Year of experiment	No. of experiment	*Variety	Percentage of total nitrogen of soil: before jute was sown	after harvest of jute at: prebud stage	bud stage	flower stage	pod stage
1950	I	Fanduk	0·11	0·13	0·11	0·14	0·13
		D-154	0·11	0·15	0·13	0·10	0·11
	II	Fanduk	0·11	0·14	0·11	0·12	0·12
		D-154	0·11	0·13	0·12	0·09	0·12
1951	I	Fanduk	0·10	0·13	0·08	0·12	0·14
		D-154	0·10	0·12	0·13	0·09	0·11
	II	Fanduk	0·09	0·09	0·08	0·12	0·14
		D-154	0·09	0·10	0·12	0·12	0·12

*Two varieties of *C. capsularis*—Fanduk (early) and D-154 were only included in this experiment.

It may be seen from the above table that though the total nitrogen increases, after a crop of jute, the amount varies considerably depending on time of harvest and on variety.

In Table III, the data for total nitrogen are presented plotwise for the season 1952 (before and after jute) and also data for the same plots at after-jute crop of 1953 season, when the experiments were carried out at the Barrackpore farm. In both the seasons, the crop was harvested at the pod stage. 4 varieties of jute *C. olitorious* improved strain 0-632 and standard strain C. G. and *C. capsularis* improved strain C-212 and standard strain D-154 were grown under manured and unmanured conditions. Fertilizer added was ammonium sulphate equivalent to 50 lb nitrogen per acre.

TABLE No. III

Change in total nitrogen of soil due to cropping with jute

Plot No.	Variety grown	Treatment	per cent total nitrogen before jute 1952	after jute 1952	after jute 1953
1	C.G	Manured	0·078	0 084	0 084
2	C-39—212	,,	0·077	0.076	0·077
3	D-154	,,	0·082	0 080	0·091
4	040—632	,,	0·087	0·090	0·107
5	C G	Unmanured.	0·080	0·078	0·083
6	C-39—212	,,	0 075	0·076	0·076
7	D 154	,,	0·072	0·068	0·084
8	040—632	,,	0·090	0·089	0·107
9	040—632	,,	0·084	0 086	0·084
10	C39—212	,,	0·080	0·073	0·088
11	C G	,,	0·075	0 069	0·083
12	D-154	,,	0·097	0·095	0·103
13	040—632	Manured	3·077	0·076	0·092
14	C-39—212	,,	0·070	0·080	0·073
15	C G	,,	0·075	0·076	0·086
16	D-154	,,	0·096	0·095	0·.04
17	D-154	,,	0·380	0·088	0·083
18	C G	,,	0·077	0·378	0·089
19	040—632	,,	0·089	0·085	0·101
20	C-39—212	,,	0·111	0·102	0·105
21	D-154	Unmanured	0·070	0·081	0·079
22	C G	,,	0·080	0·088	0·087
23	040—632	,,	0·086	0·098	0·088
24	C-39—212	,,	0·097	0·104	0·111

From the preceeding table, it may be seen that there has been in general an enrichment of the soil so far total nitrogen is concerned irrespective of varieties or manurial practices.

The changes in available soil nitrogen during the growth of the jute under influence of fertilizers were studied. The treatmentwise data for ammonia nitrogen and nitrate-nitrogen are summarised in Table No. IV for the crop seasons 1952 and 1953. There were 3 replications in randomized block layout. The variety grown was *C. olitorious* improved strain 0—632.

TABLE No. IV

Change in available soil nitrogen due to cropping with jute

p. p. m. NH_3 in

Period of sampling from the date of sowing	Untreated soil		Soil treated with*			
			Ammonium sulphate		Compost	
	with jute	without jute	with jute	without jute	with jute	without jute
1952 crop season						
0 days	13	13	13	10	7	13
after 2 weeks	52	36	84	112	42	36
6 "	50	65	65	68	64	63
10 "	8	8	11	13	9	10
14 "	0	11	1	5	1	6
22 "	3	9	3	2	0	6
29 "	10	7	9	6	12	6
42 "	4	4	3	3	0	0
0 days						
1953 crop season						
after 2 weeks	16	16	22	26	18	14
6 "	62	15	29	140	25	19
10 "	15	11	27	15	26	13
11 "	16	16	26	16	22	16
12 "	177	0	4	4	1	26
13 "	67	0	6	23	210	34
16 "	14	1	12	8	23	12

p. p. m. NO_3

Period of sampling from the date of sowing	Untreated soil		Soil treated with			
			Ammonia sulphate		Compost	
	with jute	without jute	with jute	without jute	with jute	without jute
1952 orop season						
0 days	134	183	302	326	326	314
after 2 weeks	136	102	233	248	139	182
6 "	234	226	231	245	229	224
10 "	20	31	82	15	0	27
14 "	210	45	395	23	208	33
22 "	35	23	58	22	48	25
29 "	35	25	57	21	70	25
42 "	42	13	21	16	121	64
1953 season						
0 cays of						
after 2 weeks	70	70	25	40	75	60
6 "	45	60	20	...	0	...
10 "	35	35	30	20	15	50
11 "	55	0	134	30	0	10
12 "	14	2	25	25	124	40
13 "	40	45	55	30	35	40
16 "	40	20	30	25	45	35

*Ammonium sulphate and compost were added as equivalent to 150 lbs nitrogen per acre.

From the above table, it may be seen that plots cropped with jute contained more available nitrogen after a certain period from date of sowing depending on season. This period is usually 2—3 weeks after the maximum leaf-fall was noticed.

Variation of available nitrogen due to growing of jute and paddy was determined. The treatmentwise data are summarised in Table No. V. There were 3 replications in randomized block layout. The experiment was carried out in 1952 season at the Barrackpore farm, both in midland and in highland.

TABLE No. V

Variation of available nitrogen due to growing of jute and paddy

Variety	Time of harvest of jute	Treatment	Before jute NH_3—N in p. p. m.	Before jute NO_3—N in p. p. m.	After paddy NH_3—N in p. p. m.	After paddy NO_3—N in p. p. m.	After paddy NH_3—N in p. p. m.	After paddy NO_3—N in p. p. m.
Midland								
C. capsularis Jute and Paddy								
Fanduk	Early	15 lb N before jute	21	200	9	22	17	43
	,,	15 lb N before jute and 15 lb N before paddy	15	108	—	—	13	26
	Late	15 lb N before jute	20	157	6	11	105	76
	,,	15 lb N before jute and 15 lb N before paddy	20	136	8	17	26	20
D-154	Early	15 lb N before jute	15	139	8	12	13	19
	,,	15 lb N before jute and 15 lb N before paddy	17	152	—	—	11	30
	Late	15 lb N before jute	21	155	10	28	8	71
	,,	15 lb N before jute and 15 lb N before paddy	19	130	7	14	9	24
		Jute alone						
		15 lb N before jute	17	124	10	22	—	81
		30 lb N before paddy	17	167	10	34	14	—

Variety	Time of harvest of jute	Treatment	Before jute NH$_3$—N in p. p. m.	Before jute NO$_3$—N in p. p. m.	After paddy NH$_3$—N in p. p. m.	After paddy NO$_3$—N in p. p. m.	After paddy NH$_3$—N in p. p. m.	After paddy NO$_3$—N in p. p. m.
		Paddy alone 15 lb N before paddy	16	155	—	—	15	20
		30 lb N before paddy	17	157	—	—	12	73
		Unmanured jute alone	14	131	6	7	10	28
		Jute and paddy	14	131	8	18	74	36
		Paddy alone	20	166	5	6	8	36
Highland *C. olitotious*		Jute and paddy						
CG	Early	15 lb N before jute	13	75	19	32	11	32
	,,	15 lb N before jute and 15 lb N before paddy	9	105	23	33	11	35
	Late	15 lb N before jute	10	105	6	29	18	45
	,,	15 lb N before jute and 15 lb N before paddy	7	79	5	30	21	53
		Jute alone 15 lb N before jute	8	75	18	47	18	39
		30lb N before jute	9	85	12	47	16	58
		Paddy alone 15 lb N before paddy	9	114	15	47	8	29
		30 lb N before paddy	12	109	12	59	5	35
		Unmanured Jute alone	10	82	16	28	16	45
		Jute and paddy	10	82	16	26	26	29
		Paddy alone	12	115	19	46	8	36

From Table No. V, it may be seen that the soils are in a better condition so far as available nitrogen is concerned, if the jute crop is harvested at comparatively early stage. Cropping with jute and/or jute and paddy is better than growing paddy alone for the maintenance of available nitrogen in the soil.

From the above tables, it may be clearly seen that due to cropping with jute, soil becomes rather enriched in total nitrogen. Available nitrogen status also, is higher in soils cropped with jute than even in lands kept fallow.

If all the leaves are returned to the soil, the removal by jute plants would be about 40 to 90 lb of nitrogen from an acre of land. Naturally, the question arises, how the increase in nitrogen occurs. Dhar (1946) has shown that dried *neem* leaves (*Melia azadichta Linn*) if added to the soil can fix some nitrogen. Mukherjee *et al* have also shown that dried jute leaves can fix nitrogen. Mukherjee *et al* (1954*c*) further by studying the efficacy of jute leaves as manures have shown that yield of paddy is much higher than what would be expected even if all the nitrogen supplied with dried jute leaves be available.

A much larger seed rate is used than what would be in conformity with the ultimate number of plants. The reasons of using higher seed rate have been given by Kundu and Mukherjee (1953*a*, 1953*b*). A large number of plants, therefore, are to be thinned out from jute fields. Mukherjee *et al* (1954*b*) have shown that by composting these thinned out plants, a manure as good as town compost may be obtained. Moreover no fibre is obtained from twigs and leaves which have not fallen and if they are added to the soil after harvest, additional quantity of organic matter wonld be added. From the data of De and Datta Biswas (1952) it may be seen that even straw can fix some nitrogen, though not in appreciable quantity ; the twigs which contain a large quantity of cellulosic substances are also likely to fix some nitrogen. If therefore, cultural practices as suggested by Kundu and Mukherjee (1953*a*, 1953*b*) be followed, the soil will be benefitted much.

It may, therefore, be stated that if all the nitrogen available is utilised for a crop of jute, not only the crop of jute but also the subsequent crop will be benefitted. With proper cultural practices nitrogen and organic matter balance of the soil can properly be maintained after cropping with jute.

CONCLUSION

The problem of maintaining nitrogen balance in Indian soil is becoming more and more difficult with the introduction of intensive agriculture. Application of inorganic nitrogeneous fertilizers like ammonium sulphate or sodium nitrate in large doses year after year without addition of organic matter spoils the soil tilth. In a vast country like India, it is not possible to supply all the growing needs of nitrogen from organic matter alone (from the farmyard manure sludge or composts available in the country). The alternative suggested is to green manure the soil. In normal green manuring practices, the cultivator loses one crop. A crop which can on the one hand add a considerable amount of organic matter to the soil and on the other, serves as a cash crop or food crop would be very much helpful to the cultivator. From what has been stated before, jute is a crop which is likely to fulfil these conditions.

AGKNOWLEDGMENT

The authors express their gratitude to Dr. B. C. Kundu, M.A., Ph. D., F.L.S., F.N.I., for the kind interest taken and criticisms made during the progress of the work.

LITERATURE CITED

Bal, D.V., 1925, *J. Agri. Sci.*, 15, 454.

Connell, R. P., 1942, *N.Z.J. Agri.*, 65, 5.

De, P. K. and Datta, Biswas, N. R., 1952. *India J. Agri. Sci.*, 22, 375.

Dhar, N. R., *Proc. Nat. Acad. Sci. India.*, 15, 15.

Kerr, Hemchunder, 1974, Enquiry on the cultivation of and trade in Jute in Bengal and on fibres. Calcutta.

Kundu, B. C., 1953, Annual Report, *Jute Agri. Res. Instt.* 1951-52.
1953*a*, *Jute Bulletin* 16.
1954*a*, Annual Report. *Jute Agri. Res. Instt.* 1952-53.
1954*b*, ,, ,, ,, ,, ,, 1953-54
1954*c*, Manuring of Jute, *Indian Central Jute Committee Calcutta.*

Kundu, B. C. and Chakravorty, S. C., 1954, *Proc. Ind. Sci. Cong. Part III*, 238.

Kundu, B. C. and Mukerjee, M. K., 1953*a*, *Jute Bulletin* 16, 303.
1936, *Indian Farming* 3 N. S., 14.

Mukherjee, M. K., Kundu, A. K. Chakravorty, S. C. and Halder, G.
1954*a*, *Proc. Ind. Sci. Cong., Part III*, 237.
1954*b*, *Jute Bulletin* 16, 234.
1954*c*, *Science and Culture*, 19, 456-457.
1954*d*, *Proc. Ind. Sci. Cong. Part III*, Unpublished.

Naithani, H. D., 1954, Private Communication.

Olsen, C., 1929, Compt. Rend. Trav. Lab. Calsbarg, 17, 1—20.

Patel, J. S. and Ghose, R. L. M., 1945, Jute Breeding Technique., *Agri. Res. Bull No.* 2. *Indian Central Jute Committee, Calcutta.*

Richardson, H. L., 1938 *J. Agri. Sci.* 28, 73-121.

JUTE AND SOIL FERTILITY

Part II—Phosphate Problem

By

M. K. MUKHERJEE, G. HALDER, A. K. KUNDU *and* S. C. CHAKRAVORTY

Jute Agricultural Research Institute, Barrackpore, West Bengal

(Received on 30th November, 1954)

INTRODUCTION

Addition of nitrogenous fertilizers has often been suggested for increasing the yield of crops in India, but with nitrogen alone paddy has not responded in many places. Warth and Shin (1919) have shown that application of nitrogenous fertilizers year after year ultimately reduces the yield of paddy as phosphates become a limiting factor. In India, the application of phosphates either alone or in combination has shown more or less better results. This is due to the fact that most of the Indian soils are very poor in available phosphates, though in many cases, the soils contain considerable amount of total phosphate. This is more so in case of red soils (Leather, 1898, Mukherjee, 1944). The source of rock phosphate in India is limited and the supply of bonemeal may not be adequate to meet the increasing demand of phosphatic fertilizers. Conversion of phosphates present in the soil to an available form, may therefore, be considered to be very important.

It is well- known that availability of a soil nutrient varies from crop to crop and depends also on climate (Fraps, 1909). Jute is a crop which takes up considerably larger quantity of phosphate (Kundu and Chakravorty, 1954 ; Mukherjee and Chakravorty, 1954) than what would be expected from the available phosphate status of the soils. Most of these phosphates accumulate in the leaves of the plants (Kundu, 1953, Mukherjee and Halder, 1953). Kundu and Mukherjee (1953, 1954) have shown that a considerable number of leaves fall during the growth of the plant. By gradual decomposition these leaves may supply to the succeeding crop, considerable amount of phosphate (Mukherjee, 1951, Chakravorty, Mukherjee and Roy, 1951 ; Mukherjee *et al* 1954). It was, therefore thought desirable to study the change in such forms of soil phosphates which are likely to be available due to growing of jute.

METHODS, RESULTS AND DISCUSSION

Soil samples were taken from at least five places in each plot at 0″-6″ depth and were thoroughly mixed. These were then dried in air by spreading in thin layers on enamelled dishes. The soils were then powdered to pass through a 2 mm sieve. Details about determination of available and other forms of phosphate are same as described previously by Mukherjee (1941, 1951, 1953).

Data for available phosphate by Williams' method of soils drawn before and after jute are summarised and presented treatmentwise in Table I.

TABLE No. I

Showing changes in available phosphate due to growing of jute

Year of experiment	Place of experiment	Species	Variety	Treatment	Stage of harvest	p.p.m. available P before jute	p.p.m. available P after jute
1951	Chinsura	*Capsularis*	D-154	Midland	Prebud	14·0	14·3
					Bud	14·0	15·0
					Flower	14·0	19·7
					Pod	14·0	10·2
1951	Chinsura	,,	Fanduk	,,	Prebud	14·6	14·0
					Bud	14·6	10·2
					Flower	14·6	11·4
					Pod	14·6	12·4
1951	Chinsura	*Olitorious*	CG	,,	Prebud	16·8	15·6
					Bud	16·8	19·6
					Flower	16·8	16·0
					Pod	16·8	20·7
1951	Chinsura	*Capsularis*	D-154	Lowland	Prebud	10·0	6·9
					Bud	10·0	9·4
					Flower	10·0	11·5
					Pod	10·0	23·9
1951	Chinsura	*Capsularis*	Fanduk	Lowland	Prebud	10·0	9·5
					Bud	10·0	13·1
					Flower	10·0	6·9
					Pod	19·0	13·5
1952	Barrackpore	*Olitorious*	0-40-632	Compost 6 cart loads/acre	Pod stage	101	83
				,, 12 ,,	,,	94	98
				,, 18 ,,	,,	103	161
				,, 24 ,,	,,	114	216
				Super-phosphate			
				100 lbs/acre	,,	108	152
				200 lbs/acre	,,	98	66
				300 lbs/acre	,,	101	204
				400 lbs/acre	,,	108	194
				$(NH_4)_2SO_4$ 125 lbs/acre	,,	167	66
				,, 250 lbs/acre	,,	171	135
				,, 375 lbs/acre	,,	149	179
				,, 500 lbs/acre		152	112
				A mixture of equivalent nitrogen content from $(NH_4)_2SO_4$ and $NaNO_3$ at the rate of 80 lb N_2/acre	,,	97	67
				Do. 160 lb N_2/acre	,,	100	51
				Do. 240 lb N_2/acre	,,	92	62
				Do. 320 lb N_2/acre	,,	95	47

Year of experiment	Place of experiment	Species	Variety	Treatment	Stage of harvest	p.p.m. available P before jute	p.p.m. available P after jute
1951	Chinsura	*Capsularious*	D-154	$P_1N_0K_0$	Pod stage	37	32
				$P_1N_2K_0$	,,	37	16
				$P_1N_2K_1$	,,	37	20
				$P_1N_0K_1$	,,	37	24
				Control	,,	37	23
		Olitorious	CG	$P_1N_0K_0$	,,	33	72
				$P_1N_2K_0$	,,	33	53
				$P_2N K_1$	,,	33	68
				$P_1N_0K_1$	,,	33	39
				Control	,,	33	44

N. B.—P_1 — 40 lbs P_2O_5 from super--posphate/acre
N_2 — 40 lbs N_2 from ammonium sulphate/acre
K_1 — 25 lbs K_2O from muriate of potash/acre.

From this table, it may be seen that after jute, the change of available phosphates have been apparently very irregular. It has increased in some cases and decreased in others. At Chinsura, the available phosphate generally decreased in case of *Capsularis* lowland experiments, whilst generally it has risen in *Olitorious* highland experiments. Under Barrackpore highland conditions, also the change has been irregular. Whether this is due to the fact that when the samples were drawn immediately after harvest, the fallen leaves did not decompose or for other reasons was also tested. The data of samples drawn after considerable lapse of time after harvest are presented in Table No. II.

TABLE No. II

Showing changes in available phosphate due to growing of jute
(Time of sampling 2 months after harvest)

Year of experiment	Plot No.	Species	Variety	Treatment (manured with ammonium sulphate @ 40 lbs/acre)	Stage of harvest	p. p. m. available P before jute	p. p. m. available P after jute
1952-53	1	C. Olit.	C G	Manured	Pod	167	385
Barrackpore	2	C. Cap.	C-39—212	,,	,,	141	370
	3	C. Cap.	D-154	,,	,,	189	278
	4	C. Olit.	O40—632	,,	,,	196	294
	5	C. Olit.	C G	Unmanured	,,	145	313
	6	C. Cap.	C-39—212	,,	,,	106	333
	7	C. Cap.	D-154	,,	,,	159	400
	8	C. Olit.	O40—632	,,	,,	164	357
	9	C. Olit.	O40—632	,,	,,	130	417
	10	C. Cap	C-39—212	,,	,,	167	625
	11	C. Olit.	C G	,,	,,	164	286
	12	C. Cap.	D-154	,,	,,	169	294
	13	C. Olit.	O40—632	Manured	,,	120	1111
	14	C. Cap.	C-39—212	,,	,,	136	385
	15	C. Olit.	C G	,,	,,	137	370

Year of experiment	Plot No.	Species	Variety	Treatment (manured with ammonium sulphate @ 40 lbs/acre)	Stage of harvest	p. p. m. available P before jute	after jute
	16	C. Cap.	D-154	Manured	Pod	196	322
	17	C. Cap.	D-154	,,	,,	97	357
	18	C. Olit.	C G	,,	,,	141	1006
	19	C. Olit.	O40—632	,,	,,	141	370
	20	C. Cap.	C-39—212	,,	,,	116	204

Under tropical conditions, not only available phosphate as shown by dilute acid extractions but also easily oxidizable organic alkali soluble phosphates become available (Spencer and Stewart, 1934; Das, 1949) and data for alkali soluble easily oxidizable organic phosphates are presented in Table No. III.

TABLE No. III

Changes in alkali soluble easily oxidizable organic phosphorus due to growing of jute

Year of experiment	Place of experiment	Species	Variety	Plot No.	Stage of harvest	p. p. m. before jute	organic P after jute
1935	Barrackpore	*Olitorious*	O40—632		Pod stage		
				1		91	526
				2		152	476
				3		222	625
				4		74	455
				5		208	435
				6		133	513
				7		250	606
				8		448	571
				9		449	400
				10		167	769
				13		189	1000
				14		227	476
				16		167	714
				17		192	606
				18		135	741
				19		286	455
				20		156	513
				21		167	357
				24		313	667
				27		189	689
				28		204	741
				29		263	667
				31		161	200
				32		93	541
				34		256	513
				35		294	625
				37		128	571
				38		101	555
				39		166	555
				40		227	571
				41		159	645
				42		250	714

It may be seen from the table No. III that alkali soluble easily oxidizable organic phosphorus has increased after a crop of jute.

Data for available phosphorus by semi-normal acetic acid solution method of typical jute soils are given in Table No. IV.

TABLE No. IV

Available phosphate present in typical jute soils

Locality	p. p. m. available P
1. Prasnnanagar, Belakoba, Jalpaiguri, West Bengal	11·0
2. Belakoba, ,, ,,	9·4
3. Jamadarpur, ,, ,, ,,	17·6
4. Kachukhola, Nowgong, Assam	15·9
5. Sealmarhi ,, ,,	11·7
6. Malay ,, ,,	10·5
7. Chotahybar ,, ,,	7·8
8. Dimruguri ,, ,,	7·7
9. Kabliparah ,, ,,	23·6
10. Shyamsundarpur, Kendrapara, Orissa	7·4
11. Do ,, ,,	7·4
12. Do ,, ,,	8·1
13. Saharsa, Bihar	22
14. Saderpur, Sitapur, U. P.	63
15. Tambore, ,, ,,	11
16. Lakhimpur, U. P.	13
17. Dharamshala, Cuttack, Orissa	74
18. Kashipur, Nainital U. P.	46
19. Gograghat, U.P.	28
20. Nilganj, (Afzal modi), Barrackpore, West Bengal	112
21. ,, (Mustafa Mandal), ,, ,, ,,	70
22. Bhadrak, Balasore, Orissa	nil
23. Forbesganj, Purnia, Bihar	58
24. Sreekrishnapur, Baraset, West Bengal	50
25. Kazipara, Baraset West Bengal	49
26. Basirhat, West Bengal	28
27. Supaul, Sharasa, Bihar	33
28. Madhupur, Sharsa, Bihar	33
29. Rashara, Ballia, U.P.	251
30. Biraswati, Kendrapara, Orissa	30
31. Patari, Matihari, Bihar	59
32. Matihari, Bihar	69
33. Sewrahi, Deoria, U. P.	80
34. Tukima, Anandpur, Orissa	23
35. Rupaspur, Dhamdaha, Purnea, Bihar	95
36. Murliganj, Saharsa, Bihar	63
37. Islampur, Purnea, Bihar	108
38. Jhanjharpur, Dharhanga, Bihar	160
39. Korha, Rupsapur, Bihar	96
40. Hatha, Kesargnaj, Bihar	39

Data for available phosphorus by different methods of some jute soils are given in Table No. V.

TABLE No. V

Available phosphate by different methods in different jute soils p. p. m. with respect to soils as found by—

Plot No.	William's method	Truog's method	Egnes's method	Wiscon-sin's method	Pennsyl-vania method	Michigan method	Kentucky method
N.P.C. 1	61	54	15·4	38	9·3	83	91
6	98	101	15·6	36	8·6	85	70
33	60	68	15·8	39	8·6	76	102
40	120	250	15·9	50	12·2	68	112
S. S. 1	102	155	2·6	32	7·7	66	45
2	29	33	1·1	5	7·8	6	17
4	52	31	0·3	3	0	6	15
9	58	34	0·3	9	8·7	15	18
V. T. 8	67	133	14·8	55	14·6	100	98
9	212	147	11·9	46	14·3	51	139
23	141	179	14·8	61	12·6	89	79
M. 2	73	116	18·7	60	17·3	86	85
8	48	73	15·8	63	0	78	54
15	46	82	17·0	69	8·7	53	54
16	136	149	18·6	48	10·3	85	112
24	95	98	16·3	21	16·0	93	106

Though the quantity of available phosphorus present, show wide variation yet they are comparatively richer than soils where other crops are usually grown. This is due to growing of jute in these soils for a pretty long time.

Jute fibre of commerce is obtained after retting of the main stem, when the fibre gets separated The fibre and the wood are almost all cellulosic matter containing practically no phosphate. The phosphates contained in the stem come into solution due to the microbial action as will be seen from the Table No. VI.

TABLE No. VI

Changes in water soluble inorganic phosphate in retting water with time

p. p. m. dissolved inorganic phosphate (P)

Nos. of days from start	O40—632 *Olitorious*	Nos. of days from start	C-39—212 *Capsularis*	C G *Olitorious*	D-154 *Capsularis*
0	0	0	0·09	0·09	·09
1	0	1	0·8	·8	2·0
2	0	4	4·0	2·1	5·6
3	0·66	6	3·1	7·9	3·3
4	·67	8	...	2·3	...
5	·96	11	4·4	2·7	4·8
6	1·39	13	...	...	...
7	1·90	19	7·1	3·9	9·8
8	1·53	23	6·3	2·9	9·0
9	1·94	28	3·4	1·6	3·2
10	3·45	33	2·3	1·0	1·9
11	1·39	36	9·0	4·8	9·2
12	0·66	44	...	10·5	...
13	0·66	60	0	0	0
14	0				
15	0				
16	0				

The lowering of the amount of dissolved inorganic phosphates with time is due to the conversion of some of the dissolved inorganic phosphates by the micro-organisms to organic forms. Even then, it may be added that the retting water contain a large quantity of inorganic water soluble phosphates as may be seen from the following table (VII), where retting was continued for a fairly long time.

TABLE No. VII

Water soluble inorganic phosphate in different retting water

Places of collection	p. p. m. P
Udaipur (Ranaghat, Nadia)	42·2
Gopalnagar (Nadia)	171·0
Temohoni (Habibpur, (Nadia)	29·0
Nidkur (Fulia, Nadia)	510·0
Gaira (Basirhat)	362·0
Laxminathpur (Baduria, Basirhat)	29·0
Mathurapur (Kholapota, Basirhat)	833·0
Ramnarayanpur (Basirhat)	658 0
Bonda (Baraset)	357·0
Madhya-vizla (Singur)	29 0
Mogra (Hoogly)	185·0
Nilganj	500·0

It may, therefore, be stated that if these retting water be added to the paddy fields near about, the crop will get a considerable amount of readily available phosphorus. Further, it may be stated that compost prepared from thinned out jute plants also may supply quite a good amount of available phosphorus (Mukherjee *et al*, 1954).

CONCLUSION

The problem of phosphates in Indian soils is more of conversion of total phosphates present in the soil to an available form than of addition of phosphatic fertilizers. Growing of a crop which can take up comparatively more phosphate and then addition of it to the soil may serve very well to convert unavailable phosphates to available forms. A crop which can take up comparately more phosphates and from which all portions containing phosphates can be returned to the soil will be better, if at the same time, it gives the cultivator a monetory return and improves his soil. Jute is a crop which fulfils these conditions as may be seen from the tables presented earlier.

Red soils of India occupy a large area. They are very poor in their available phosphate (Mukherjee, 1941, 1944, 1951). In these red soil areas, several multipurpose projects are being sponsored. Mention may be made of Damodar Valley, Hirakud and Mayurakshi projects. In a study of Damodar Valley soils, Chakravorty, Mukherjee and Roy (1951) and Mukherjee (1951) have also shown the peculiarity of such soils and they have suggested for their improvement by green manuring with the addition of phosphates. Jute can be grown in the Mayurakshi, Damodar and Hirakud areas with irrigation and it is felt that if jute be grown in these areas, the soils will become enriched in available phosphate as well as nitrogen, and it will be more so if all the leaves be shed in the fields and thinned out plants and twigs are returned to the fields and retting water, silt and mud from retting tanks be added to the soils.

ACKNOWLEDGMENT

The authors express their gratitude to Dr. B. C. Kundu, M.A. Ph.D., F.L.S., F.N.I., for their kind interest taken and criticisms made during the progress of the work.

LITERATURE CITED

Chakravorty, J. N., Mukherjee, M. K., Roy, G. S., 1951, *Proc. Ind. Sc., Cong. III.* p. 171.

Das, S , 1949, *Indian Jour. Agri. Sci.*, 19, 41.

Fraps, G. S., 1909, *Text, Agri. Expt. Stn. Bull.*, 126.

Kundu, B. C., Annul Report. *Jute Agri. Res. Inst.*, 1951-52.

Kundu, B. C., and Mukherjee, M. K., 1954, *Ind. Farming, III. N. S.* 14—1953. *Jute, Bull.*, 16, 303.

Kundu, B. C., and Chakravorty, S. C., 1954, *Proc. Ind. Cong., III.* 238.

Leather, J. W., 1898, *Agri. Ledger. Cal.*

Mukherjee, M. K., 1944, *Ph. D., Thesis, Dacca University.* 1941, *Ind. Jr. Agri. Sci., II,* 243. 1951, *Proc. Ind. Sc. Cong., III,* 172, 1953. *Proc. Ind. Sc. Cong., III,* 137, 1952. *Jr. Sc. Club. Cal., VI.*, 29.

Mukherjee, M. K. and Halder, G., 1953. *Proc. Ind. Sc. Cong., III,* 137.

Mukherjee, M. K., Chakravorty, S. C., Kundu, A. K. and Halder, G. 1955 *Proc. Ind. Sci. Cong., Part III,* (Unpublished).

Mukherjee, M. K. and Chakravorty, S. C., 1955, *Proc. Ind. Sci. Cong., Part III,* (Unpublished).

Spencer, V. E. and Stewart, R., 1934, *Soil Sc.* 38, 65.

Warth, F. J. and Shin, M. P., 1919. *Imp. Inst. Agri. Res. Mem. Chem. Ser.* 5, 131.

Mukherjee, M. K. *et al, Jute Bull.*, 1954. 16, 334.

MINERALIZATION OF ORGANIC PHOSPHORUS IN SOILS UNDER TROPICAL CONDITIONS

By

S. N. SAXENA *and* S. KASINATHAN

College of Agriculture, Banaras Hindu University

Communicated by Prof. S. Ghosh

(*Recevied on 6th March, 1954*)

Tropical agriculture presents several points of contrast from that of the colder countries of the west, and among the most striking are the results of the fertilizer trials with phosphates and potash of commerce. The popularity of these two classes of fertilizers is almost universal in those parts of the world, its experience in India for most of the crops is really depressing. This becomes all the more difficult to explain if we view it against the background of comparatively slendour resources of our soils in respect of phosphorus. The importance of a correct understanding of such obviously conflicting experiences need no emphasis.

Studies on phosphorus utlization show that the super-phosphate applied to lands is used up only to the extent of 15% the remaining either sendered unavailable or otherwise lost. On the other hand recent work on the mode of phosphorus manuring has given strong indications that organic manures are better sources of phosphorus to plants [3, 5, 15, 18] and in line with these findings Fuller has shown that plants grown on Algae phosphorus contain more phosphorus than those raised on complete inorganic neutrient forms.[12] Long duration tests at Rothamsted also go to show that manure P has considerable and perhaps needy availability in soils than its nitrogen. A normal dose of basal manure makes a reduction of as much as 45% P_2O_5 in the most profitable doses of a phosphatic.[19] It appears not improbable that the failure of the inorganic phosphate in the tropics is due to the comparative instability of the organic sources under the climatic conditions of the places, in other words of rapid mineralization and fixation of the mineralized forms. It seems to be of considerable value to place phosphorus manuring of tropical soils on surer basis and it is proposed in this communication to present the results of studies made on the mineralization of organic phosphorus in these laboratories.

Fixation of phosphate has from sometime past invited much attention. It has been observed in almost all cases of soils that available phosphorus materials when added to soil get converted to relatively insoluble forms thereby greatly impairing the availability of fertilizer as a plant nutrient. It is now accepted that soluble forms of phosphorus materials are only available better for semetime but upon aging there is no difference in the avilability of organic and inorganic forms.[18] Various views have been put forward from time to time regarding phosphorus fixation. In organic fixation in the form of $Ca_3(PO_4)_2$ or carbonato

apatite,[17] phosphates of iron and aluminium or combination of phosphates with clay minerals has often been suggested.[19] It does not appear however that total fixation is inorganic in nature, it is partly organic also.[10] If the microflora is active and available carbon compounds abundant the fixation is mostly organic in form. There is enough evidence to support that fixation is partly due to microbial immobilisation of available phosphorus. The extent of microbial fixation depends upon a number of soil and organic matter factors [10], [17]. Very recently Fuller and McGeorge have concluded that ploughing down of roots and other low phosphorus materials results in the immobilisation of available inorganic phosphorus.[10] Apart from this it appears from Eide and Black's work that organic phosphorus materials are more important for high temperature conditions existing in tropics as against low temperature conditions of temperate countries, because phosphorus in organic form gets mineralized slowly whereas in high temperatures the processes are too quick.[9]

In the present investigation an attempt has been made to study the mineraliza tion of organic phosphorus compounds in compost and farmyard manure. This study is quite important for it throws much light upon the availability and fixation of phosphates through organic form in the ordinary course of farming.

MATERIALS AND METHODS

A soil sample was obtained from the Banaras Hindu University and was dried, powdered and sieved through standard seives. The organic carbon / organic phosphorus ratio of the soil was 189·92. The samples of compost and FYM were collected from the farm. Two types of samples were chosen for study. The first type were old org. C/org. P. = 140 in case of FYM and 150 in case of compost. The other type were quite fresh and had hardly gone any major decomposition.

Twenty five soil samples were also obtained from various places of Banaras district and hilly tracts of Satna district. Preliminary experiments to determine organic fixation were performed. A dozen soil samples from the above 25 were chosen and to all of them glucose as 1% carbon, nitrate as ·05% nitrogen was added. A similar dozen set were again prepared and treated with ·02%P in the from of KH_2PO_4. A third containing only soil samples without any C,N,P, treatments was set apart. 100 gms of each samples of the mixtures were put in petri-dishes and left in the atmospheric conditions at about 35°C. Water was added to give nearly 60% saturation. Analysis was made after 1 and 2 weeks.

Experiments for studying the decomposition of FYM and compost were also started. The soil sample from B. H.U. area was mixed with different samples of old and new FYM and compost in the ratio 25:1·5, 25:2, 25:2·5 25:3. Pots were taken which can hold nearly 2·5 kgm of soil and were filled up with 2·5 kgm of these mixtures. To a similar set of 2·5 kgm each super-phosphate was added at a rate of ·05%P. All pots were maintained at a definite moisture level and loss on evaporation was recouped by weighing and adding requisite quantity of water. Decomposition was continued under optimum moisture and temperature conditions for 15 weeks. Samples were taken out after thorough mixing of the soil in pots after the period of 1[1], 3, 6, 9, 12 and 15 weeks for analysis. The experiments were all run in duplicates for analysis.

Total P of soil were determined colorimetrically. The solutions for phosphorus estimation were made according to $Mg(NO_3)_2$ fusion method of A.O.A.C.

The colorimeteric determination was done after removal of iron and silica from the solution according to the modification of Armstrong Black. [1,16,8].

Total organic P was determined by the technique of Wrenshall and Dyer (1939). The final determination was done on a Gallenkamp photoelectric colorimeter using a red filter. The colour development was done by the methed of Dickman and Bray ([6,8]).

Inorganic P was determined by the difference detween total and organic P.

Water soluble P was determined by extraction of sample with water, evaporating the extract and igniting. HCl was added to dissolve and the colour was developed as previously. Determination of organic carbon was done by carbon combustion furnace according to standard A.O.A.C. method. Correction for carbonate carbon was also made.[1]

RESULTS

Increase in organic P content in soils

12 samples chosen for the purpose had a varying P and organic P content. The 1st and 2nd week analysis of sample Nos. X6 and XI are shown in table No. 1.

TABLE No. 1

Results of samples of two soils treated with glucose, nitrate and phosphate

Sample	Time	Total P	Organic P		Inorganic P		W. S. P	Org. C.
	Days	p. p. m	p. p. m	%total p	p. p. m	%total p	p. p. m	%
XI	0	394	20·5	5·27	373·5	94·73	5·5	0·31
	7	394	20·5	5·27	373·5	94·73	6.0	0·30
Control	14	394	20·0	5·07	374·0	94·93	6·0	0·28
XI	0	394	20·0	5·07	374·0	94·93	5·5	1·31
	7	396	32·0	8·08	364·0	91·92	0	0·99
C+N	14	397	42·0	10·57	355·0	89·43	0	0·75
XI	0	591	20·0	3·46	571·0	96·54	53·0	1·31
	7	593	34·0	5·73	559·0	94·27	32·0	0·95
C+N+P	14	593	45·0	7·58	548·0	92·42	20·0	0·68
X6	0	1008	55 0	5·45	953·0	94·55	5·0	0·93
	7	1008	54·0	5·35	954·0	94·35	7·0	0·91
Control	14	1008	53·0	5·25	955·0	94·75	8·0	0·90
X6	0	1005	55·0	5·47	950·0	94·53	5·0	1·93
	7	1005	73·0	7·27	932·0	92·74	0	1·49
C+N	14	1005	75·0	7·46	930·0	92·54	0	1·16
X6	0	1206	55·0	3·56	1151·0	95·44	38·0	1·93
	7	1208	75·0	6·20	1133·0	93·80	16·0	1·46
C+N+P	14	1208	74·0	6·12	1134·0	93·88	8·0	1·10

In the above table we find that in the case of sample No. XI the organic phosphorus increase from 20 p. p. m to 42 p. p. m in 2 weeks time and consequently there was a reduction of water soluble phosphorus. In about a weeks

time the water soluble phosphorus became 0. In case of control to which neither C, N or P was added there was slight mineralization. This was probably due to the fact that the soil did not have available carbon materials that can be utilised by microflora. Similarly in other cases also we found the activity of microbial population in presence of available carbon materials. In table No. 1 in case of X6 we find that organic phosphorus starts minerilization also after attaining a critical point. This shows that micro-organisms are assimilating organic P in soils but the process of death and decay is also going on side by side.

In case of sets treated with KH_2PO_4 the assimilation is more in 2 weeks time. It is probably due to the fact that P was limiting factor in the growth of micro-organisms. Most of the soil P is unavailable to plants and also to micro-organisms and therefore any supply of soluble P materials is likely to result in the increase of microbial activity and consequently more of organic carbon is decomposed and more of organic P is assimilated. It also appears however that even in presence of all available organic and inorganic materials, the microbial assimilation stops at a particular critical point.

Decomposition of Farm Manure.—When natural organic materials are added to the soils it results in the increase of microbial activity and consequently an increase in organic phosphorus of soil. The soil microbial population requires nearly 4 gm P per 100 units of carbon decomposed and the activity will continue till all energy material is consumed. The sources of phosphorus in soils for microbial assimilation are either organic or inorganic in nature and the water soluble inorganic phosphorus compounds are first utilized in order of preference. However synthesis is not the only process going on. Side by side the mineralization also proceeds. The old micobial tissues die and decay and organic P materials present in microbial cells are let loose for decomposition. The hydrolysing enzymes then react upon them and form the soluble inorganic P materials which may or may not be assimilated by plants or micro-organisms.

The results of decomposition experiments with FYM are presented in table No. 2.

TABLE No. 2

Old FYM mixed with the soil with and without super-phosphate

Sample	Time	Total P	Organic P		Inorganic P		Org. C	Org. C/ Org. P
	Weeks	p.p.m	p.p.m.	% total P	p.p.m	% total P	%	
250 gm soil	0	642	130·5	20·32	511·0	79·68	2·03	155·5
20 gm FYM	1½	642	106·0	16·51	536·0	83·49	1·84	173·6
	3	642	99·0	15·42	543·0	84·58	1·71	172·7
	6	642	88·0	13·70	554·0	86·30	1·51	171·6
	9	642	79·0	12·30	563·0	87·70	1·35	170·8
	12	642	71·0	11·05	571·0	88·95	1·23	173·2
	15	642	66·0	10·28	576·0	89·72	1·13	171·2
250 gm soil	0	1142	130	11·38	1012	88·62	2·03	155·0
20 gm FYM	1½	1142	120	10·50	1022	89·50	1·82	151·6
Super-phos-	3	1142	101	8·84	1041	91·16	1·68	166·3
phate ·05%P	6	1142	86	7·53	1056	92·47	1·47	170·8
	9	1142	75	6·56	1067	93·44	1·30	173·3
	12	1142	68	5·95	1074	94·05	1·18	173·5
	15	1142	63	5·51	1079	94·49	1·08	171·2

In case of old FYM the organic phosphorus content is decreasing with time. At the beginning the organic phosphorus was 130·5 p.p.m. and towards the end it is 66 p.p.m. This shows clearly that minerlization is the principal process going on. It is evident that organic phosphorus in the above sample is more than the critical value for minerlization and consequently there is constant process of decomposition going on whereby inorganic phosphorous is released from organic combination. In mixture where super-phosphate is added it is observed that due to excessive available phosphorus the minerlization process is delayed and rather results in slight synthesis. In table No. 2 it is observed that in case of sample treated with super-phosphate the value for organic phosphorus decreased from 130 to 120 whereas with sample which was not treated with super-phosphate the decrease was from 130·5 to 106. This result clearly indicates that the process of minerlization is delayed. However the minerlization after 3 weeks is normal. The result of decomposition experiments with fresh FYM are presented in table No. 3.

TABLE No. 3

Fresh FYM mixed with soil, with and without super-phosphate

Sample	Time	Total P	Organic P		Inorganic P		Org. C	Org. C/ Org. P
	Weeks	p.p.m	p.p.m	%total P	p.p.m	total P	%	
250 gm soil	0	655	76·0	11·60	579·0	88·40	1·81	238·1
20 gm FYM	1½	655	85·0	12·97	570·0	87·03	1·65	194·1
	3	655	90·0	13·74	565·0	86·26	1·55	172·2
	6	655	78·0	11·90	577·0	88·10	1·34	172·0
	9	655	68·0	10·38	587·0	89·72	1·17	172·0
	12	655	60·0	9·16	595·0	90·84	1·03	171·5
	15	655	54·0	8·24	601·4	91·76	0·93	172 2
250 gm soil	0	1155	76·0	6·58	1079·0	93·42	1·81	238·1
20 gm FYM	1½	1155	85·0	7·35	1070·0	92·65	1·64	192·9
super-phos-	3	1155	91·0	7·87	1064·0	92·13	1·53	168·1
phate ·05% P	6	1155	77·0	6·66	1078·0	93·34	1·32	171·4
	9	1155	66·0	5·71	1089·0	94·29	1·14	172·7
	12	1155	57·0	4·93	1098·0	95·07	0·99	173·7
	15	1155	52·0	4·50	1103·0	95·50	0·89	171·1

In case of soil treated with fresh sample of FYM, organic phosphorus rose from 76 p.p.m. to 90 p.p.m. in three weeks time and after which minerlization started and continued till 15 weeks. It appears from the above result that in case of fresh FYM the organic carbon is available for about 6 weeks and when the supply gets exhausted or the organic P content reaches a critical value the minerlization sets in. We can safely say in the light of the above result that when fresh materials are added in the form of FYM the organic P increase are of more synthesis by micro population may continue for about 1½ to 2 months and after that the minerlization may be the dominant process In case of old decomposed FYM it appears the critical value of mineralization already exists and therefore there is a constant decomposition of organic phosphorus in soil and that is why mineralization is dominant right from the beginning. In case of fresh FYM with super-phosphate the results indicate (table No. 3) that there is more microbial synthesis as result of increase in available phosphorus. In this case the synthesis continued for more than 3 weeks. The organic phosphorus rose from 76 to 91 in 3 weeks time and then the minerlization came in. Here also super-phosphate results in slight more synthesis.

DECOMPOSITION OF COMPOST

Decomposition of compost also presents similar results with that of FYM. The only different in the behaviour of the two lies in the fact that leaf compost is richer in fresh stage in the available carbon content and due to this fact mineralization proceeds after a longer time.

The results of compost decomposition are presented in Table No. 4.

TABLE No. 4

Old compost mixed with soil, with and without super-phosphate

Sample	Time Weeks	Total P p. p. m.	Organic P p. p. m.	Organic P %total P	Inorganic P p. p. m.	Inorganic P %total P	Org. C %	Org. C/ Org. P
250 gm soil	0	592·0	114·5	19·34	477·4	80·65	1·90	166·0
20 gm compost	2½	592·0	101·0	17·06	491·0	82·93	1·72	170·3
	3	592·0	92·0	15·54	500·0	84·45	1·58	171·9
	6	592·0	80·0	13·51	512·0	86·48	1·38	172·5
	9	592·0	76·0	12·83	516·0	87·06	1·31	172·3
	12	592 0	68·0	11·48	524·0	88·51	1·17	172·0
	15	592·0	61·0	10·3	531·0	89·69	1·05	172·1
250 gm soil	0	1098	114·0	10·38	984·0	89·61	1·90	166·0
20 gm compost	1½	1098	103·0	9·38	995·0	90·61	1·70	165·0
super-phosphate	3	1098	90·0	8·19	1008·0	91·80	1·54	171·1
·05%P	6	1098	71·0	6·46	1027·0	93·53	1·23	173·2
	9	1098	61·0	5·55	1037·0	94·44	1·06	173·7
	12	1098	53·0	4·82	1045·2	95·17	0·92	173·6
	15	1098	47·0	4·28	1054·0	95·71	0·81	172·3

The table No. 4 shows the result of old compost decomposition. It is observed that organic phosphorus content decreases constantly with time. In case of sample not treated with super-phosphate the organic phosphorus content dec eased from 114·5 to 61 in 15 weeks time. The mineralization proceeds on continuously. In case of sample to which super-phosphate was added the organic phosphorus did not mineralize quickly. The action of super-phosphate only results in an increase of more organic phosphorus but the mineralization sets in after the effect of super-phosphate is lost. It is possible that the soluble phosphorus of phosphate gets fixed up.

The dccomposition of fresh compost results in an increase of organic phosphorus. The results are presented in the table No. 5. The organic phosphorus in case of sample not treated with super-phosphate rose from 70 to 80 p. p m. in 6 weeks time and did not go below the original amount even after 9 weeks of mineralization. It appears that compost organic phosphorus takes sufficiently long time for minerlization as is evident from the result. It is observed that organic phosphorus in the start was 70 p. p. m. and 15 weeks it was 64 p. p. m. and the difference in the 2 values is only 6 p. p. m. which is too small an amount. It is therefore clear that compost decomposition proceeds on without any loss of organic phosphorus in about 15 weeks time.

TABLE No. 5

Fresh compost mixed with soil with and without super-phosphate.

Sample	Time Weeks	Total P p. p. m.	Organic P p. p. m.	Organic P %total P	Inorganic P p. p. m.	Inorganic P %total P	Org.C %	Org.C/Org P
250 gm soil	0	575	70·0	12·17	505·0	87·82	1·80	257·1
20 gm compost	1½	575	78·0	13·56	497·0	86·43	1·65	211·5
	3	575	84·0	14·64	491·0	85·39	1·54	183·3
	6	575	80·0	13·91	495·1	86·08	1·39	173·7
	9	575	74·0	12·69	502·0	87·30	1·26	172·6
	12	575	67·1	11·66	507·9	88·33	1·16	172·9
	15	575	64·0	11·13	511·0	88·86	1·09	170·9
250 gm soil	0	1074	70·5	6·56	1003·5	93·43	1·81	356·7
20 gm compost	1½	1074	81·0	7·54	993·0	86·87	1·63	201·0
super-phosphate	3	1074	90·4	8·41	983·6	91·58	1·51	167·1
·05%P	6	1074	79·5	7·40	994·5	92·59	1·32	166·9
	9	1074	69·0	6·42	1005·0	93·57	1·17	171·6
	12	1074	61·5	5·72	1012·5	94·27	1·05	171·0
	15	1074	57·1	5·31	1016·9	94·68	0·97	170·0

In case of fresh compost with super-phosphate the increase in organic P content is much more higher than the previous case. Mineralization also results in the decrease of organic phosphorus only after 6 weeks time. This is due to the fact that the available organic carbon and phosphorus materials are more abundant in this case.

ORGANIC CARBON AND ORGANIC PHOSPHORUS RELATIONSHIP

It was observed in almost all decompositions studied so far that the process of synthesis stops or rather the process of mineralization overcomes the process of synthesis after a definite period and concentration of materials. It appears from the amount of organic carbon and organic P at such stages that a definite ratio is obtained after which organic carbon and organic phosphorus decompsition do not alter the final ratio. It is observed that in all tables the mineralization sets in only after a ratio of nearly 170 or more is obtained. Further we find that after the mineralization sets in the organic P decomposition are in complete harmony with organic carbon decomposition. We find in table No. 1 in case of both the samples the organic carbon by organic phosphorus ratio is 155. It is so because the FYM added has a larger amount of organic phosphorus. It is well-known that the organic carbon by organic phosphorus ratio in the old decomposed farmyard manure is much more lower than that of the soil. It is known that FYM contains nearly ·2% organic P in fresh stage and upon its decomposition a critical value for mineralization of organic phosphorus may be as high as ·3% organic P.[2] Calculating on this basis we find that organic phosphorus ratio in case of old and fresh materials may be lower than 170 or may be as high as 300 and therefore mixing of such a material with soil would lead to decrease in organic carbon by organic phosphorus ratio. The old FYM used in this particular case had a ratio of 140 and therefore mixing of this old FYM lead to a ratio of

155·5. It is observed that the lower ratio attains a value 170 very quickly *i.e.*, hardly a few days. The effect of super-phosphate on old material is that it delays in maintaining the ratio and 6 weeks may be taken up as against $1\frac{1}{2}$ week in the other case In Table No. 2 the ratio became 155·5 to 173·6 in 10 days time whereas in sample treated with super-phosphate the ratio could be obtained after 6 weeks time. With fresh materials the organic carbon decomposes quickly and organic phosphorus level increases. In both the cases of FYM and compost the ratio attained after a definite period but the period taken by compost is longer than that of FYM probably due to more of organic carbon supply. Super-phosphate in all previous cases results in delaying the maintenance of ratio. However mineralization proceeds smoothly after 6 weeks time.

It appears from the organic carbon by phosphorus ratio that a definite dependence exists in the decompositions of carbon and phosphorus and that a ratio near about 170 is attained. It is observed in a number of cases of soil samples that the ratios are very near to 170. For tropical soils it appears that ratio may be very near to 170. 25 soils of Banaras and Satna district gave ratios which varied from 155 to 184. It is possible that in cases of soil samples where ratios are low are high the organic carbon/organic phosphorus ratio is not stabilized. A number of soil samples are being obtained to study this ratio carefully. There is very little doubt that mineral soils of tropics would maintain a ratio in between 150 to 190 when stabilized because of high rate of mineralization.

DISCUSSION

Results presented here clearly indicate that microbial population plays an important role in relation to phosphrous availabilty in soils. Assimilation and minerlization are the two processes going on. Assimilation is effected only when there is an abundant supply of organic carbon, inorganic available P and other inorganic nutrients. The assimilation brings about the immobilization of available P as is indicated by the results of water soluble phosphorus utilization. It also appears that ·4% P is required in available state to effect such a conversion. If the source of carbon is readily available more of assimilation will be expected. It is also evident that if source of carbon is more available the rate will be still higher, and if the material is less available the rate will be low. The microbial population behaves in a manner so as to take up all the water soluble phosphorus first and then to utilise the other available compounds. If super-phosphate is added to soils it results in more of asssimilation because of limiting condition of available phosphorus which super-phosphate provides. But after a time the available super-phosphate gets unavailable and then its activity ceases. The minerlization then will proceed normally.

The processes of minerlization sets in only after a definite org. C/org. P ratio is obtained. In case of 25 Indian soils the ratio is found to be nearly 170. If the ratio is 170 or exceeds this the mineralization sets in and continues till the ratio is attained. It does not mean that there will be no mineralization after such a ratio is attained but the organic carbon decomposition shall be in complete harmony with that of organic P decomposition without altering the ratio.

It is clear from the results that organic matter additions for some time result in decreasing water soluble P and activity of super-phosphate is also hampered if the soil contains enough of plant residues. Any increase in available carbon and P will result in more of microbial fixation of P in soils and the mineralization may

later on transform it again to inorganic P. The dependence of organic P decomposition on organic C decomposition results in slow release of P and which helps in the economy of phosphate materials added to soils. This fixation of PO_4 in organic form not only avoids possible losses by leaching and other agencies but also helps in the constant supply of available phosphate to soils. Phosphorus fertilization in the organic form is more effective in tropical countries like India due to high temperature existing. Under these conditions we find that rate of minerlization is considerably high which may be further enhanced if plants are grown. The results of such minerlization affected by plants shall appear in our next communication.

SUMMARY

Decompositions were studied with a number of old and fresh samples of FYM and compost. It is observed that org. C/ org. P ratio is roughly constant after a definite decomposition period. The super-phosphate additions in soils results in more of microbial fixation in presence of available carbon materials. Super phosphate manuring therefore along with organic materials appear to be less effective. the organic phosphorus decompositions are found to be very high and it is suggested that in Tropical countries like India manuring in the form of organic phosphorus will be more effective.

Org. C/org. P ratio of 25 Indian soils were obtained. They range from 155 to 184.

REFERENCES

1. A. O. A. C., Methods of Analysis, 1945, Washington D. C.
2. Armi Kaila, 1949. Biological absorption of Phosphorus, *J. Soil Sci.*, Vol. 68.
3. Bear, F. E., King W. A. and Bender, C. B., 1946. The dairy cow as a conserver of soil fertility., *N. J. Agr. Expt. Sta. Pull.* 730 : 1-11.
4. Bertramson, B. R. and Stephenson, R. E., 1942. Comparative effeciency of organic P and super-phosphate in nutrition of Plants, 53 : 215-227.
5. Copeland, O. L. and Merkle, F. G., 1942. The influence of certain soil treatment upon fixation and availability of applied phosphate. *Soil Sci Soc. Amer. Proc.* 1941, 6 : 321-327.
6. C. H. Williams, 1950. Studies on soil Phosphrous., *J. Agr. Sci.* Vol. 40.
7. Chang Sing Chen. The transformation of phosphorus during the decomposition of plant materials.
8. Dickman S. R. and Bray R. H., 1941. Replacement of absorbed PO_4 from Kaolinite by fluoride.
9. Eid, M. T. and Black C. A., Kempthorne, O., 1951. Importance of soil organic and inorganic phosphorus at low and high soil temperature. *J. Soil Sci.*, Vol. 70.
10. Fuller, W. H. and McGeorge, 1950. Phosphates in Calcarious Arizona. *Soil Sci.*, Vol. 70.

11. Fuller, W. H. and Rogers, R. N., 1952. Utilisation of phosphorus from Barley residues. *Soil Soi.*, Vol. 74, 373-382.

12. Fuller, W. H. and Rogers R. N., 1952. Utilization of Algal phosphorus, *Soil Sci* , Vol. 74, 417-429.

13. Fuller, W. H. and Dean, 1949. Utilization of phosphorus from green manure. *J. Soil Sci.*, Vol. 68.

14. Guyon, G., 1946. La Valeur Des elements fertilisants du Fumier deferme. *Ann. Agron.*, 16 : 103-106.

15. Hartley, K. T. and Greenwood, M., 1933. The effect of small applications of FYM on cereals in Nigeria. *Empire. Jour. Expt. Agr.* 1 : 113-121.

16. Ian Armstrong Black, 1941. Methods of determining phosphates in soil extract. *J. Soil Sci.*, Vol. 51 : 289-298.

17. Pierre, W. H., 1948. The phosphorus cycle and soil Fertility. *J. Amer. Soc. Agron.*, Vol. 40, 1—14.

18. Pierre, W. H. Utilization by plants of P. in FYM II, 1949. *Soil Sci.*, Vol. 68.

19 Dainiel Hall, Soils.

INFLUENCE OF CALCIUM PHOSPHATE IN COMPOSTING OF ORGANIC MATTER

By

N. R. DHAR, S. M. BOSE AND A. C. GOUR

Sheila Dhar Institute of Soil Science, University of Allahabad

(Received on 7th November, 1954)

Although composting is as ancient as agriculture, the fundamental changes involved in composting of organic matter require further investigation. It is well-known that the aim of composting is to save the nitrogen, potash, phosphate and trace elements present in the natural organic substances with a C/N ratio much greater than 10, and to produce a material having a C/N ratio of about 10 as in the soil humus.

Experiments in composting of plant materials all over the world show that there is appreciable loss of nitrogen not only from the added nitrogenous substances but also from the nitrogen present in the organic matter. It appears that the loss of nitrogen in the process of composting is chiefly due to the high temperature prevailing in the compost heaps and their acidity. These lead to the marked decomposition of the unstable compound ammonium nitrite formed and decomposed in the process of nitrification of all nitrogenous substances accordingly to the following equation.

$$NH_4NO_2 = N_2 + 2H_2O + 718 \text{ KCal}$$

If the temperature of the system is not allowed to rise much and it does not become acidic the loss of nitrogen in composting can certainly be minimised. This can be achieved by repeated stirring of the materials in the compost heap and thus dissipating the heat produced in the oxidation of the carbonaceous compounds. This is not a difficult problem in a country where labour is cheap as it is in many countries of the world today.

Recently an elegant method of composting plant materials has been worked out by Dhar and Ghildyal[5] simply by adding small amount of soil to the organic matter to be composted. These authors have reported that there may be an increase of 37% of the nitrogen present in the system due to the fixation of atmospheric nitrogen in this method of composting. Similarly in a few experiments Howard and Wad have observed nitrogen fixation in composting of residues low in nitrogen content, whilst with high nitrogen content residues, there is a significant loss of nitrogen.

Dhar[4] in his Presidential Address to the National Academy of Sciences, India (1952), has stated as follows:—

"From our experiments we are convinced that calcium phosphate is helpful in the composting of plant materials *viz.*, in the absence of nitrogenous fertilizers because phosphates help in the nitrogen fixation by organic matter and hence calcium phosphate or phosphate rock should be largely used in composting."

After a systematic study of the problem of nitrogen fixation in the soil we have come to the conclusion that a mixture of all types of organic matter, *e.g.*, grass, straw, leaves, sawdust, lucerne, sunn-hemp, clover, cowdung, molasses, etc.,

and calcium phosphate when ploughed in the soil enhance the soil fertility, markedly by fixing the atmospheric nitrogen and rendering phosphates more readily available to the crops. As calcium phosphate is very valuable in improving the humus formation when added to organic matter prior to composting, we are systematically investigating the influence of different phosphates in composting organic substances.

In this communication we are submitting our results and observations on the influence of finely powdered rock phosphate, basic slag and super-phosphate in the composting of straw, cowdung and weeds kept in wooden boxes or pits.

Composting of straw, cowdung and fresh green weeds mixed with small quantities of soil in presence of rock phosphate, basic slag or super-phosphate.

Size of the boxes—30″ × 15″ × 6″

The bottom of these boxes were sealed to check losses due to leaching. A weighed amount of wheat straw or dung to be cmposted was put in the box and thoroughly mixed with ordinary soil weighing $\frac{1}{8}$th the weight of the material to be composted and the calcium phosphate to be used was also carefully mixed and distilled water was uniformly sprayed to make the moisture about 40% for enhancing the decomposition of the organic substances.

The moisture was maintained daily at the same level after recording the temperature of the compost heap in each box and the whole heap was stirred daily so that the temperature of the compost did not rise much.

At the end of definite periods of time, samples were withdrawn from each set and analysed on an oven-dry basis.

Effect of rock phosphate (Trichnopoly) and super-phosphate prepared by adding one mol H_2SO_4 instead of two mols as in super-phosphate manufacture.

Wheat straw composting. (2·5 kgms straw + 312·5 gms soil)
Analysis of wheat straw—
Moisture 10·40%
Total carbon (dry basis) = 32·6
Total nitrogen ,, = 0·65 C/N (ratio) = 50·15
Analysis of soil :—
Total carbon = 1·5690
Total nitrogen = 0·2490
(9 lbs of P_2O_5 added per ton of manure)

TABLE No. 1

Balance-sheet of Nitrogen in composting of Straw

	Initial			After 30 days				After 60 days			
	Total carbon %	Total nitrogen %	Total nitrogen in gms	Total carbon %	Total nitrogen %	Total nitrogen in gms	% increase in total nitrogen	Total carbon %	Total nitrogen %	Total nitrogen in gms	% of increase
1. Control	29·1	0·6054	17·028	19·6	1·1250	17·18	0·89	19·35	1·150	17·19	0·95
2. Treated with rock phosphate	28·7	0·5961	17·028	17·9	1·1650	18·50	8·60	17·79	1·240	18·55	8·93
3. Treated with super-phosphate	28·4	0·5914	17·028	19·7	1·3385	19·46	14·29	18·68	1·365	19·50	14·5

Balance-sheet of total Organic carbon in the composting of Straw

	Initial		After 30 days			After 60 days		
	Total carbon in gms	C/N ratio	Total carbon in gms	Total carbon in gms oxidized	Total nitrogen increase in gms	Total carbon in gms	Total carbon oxidized in gms	Increase in total nitrogen in gms
1. Control	819·92	48·0	299·1	520·8	0·152	289·4	530·52	0·162
2. Treated with rock phosphate	819·92	48·7	284·5	535·4	1·472	266·2	553·72	1·522
3. Treated with super-phosphate	819·92	48·1	286·5	533·4	2·432	266·8	553·12	2·472

Percentage of available Nitrogen after 30 days in composting of Straw

	% of ammoniacal nitrogen	% of nitrate nitrogen	% total available	Total nitrogen %	% of total $= \frac{\text{available}}{\text{total}} \times 100$
1. Control	0·0625	0·1670	0·2295	1·1250	20·4
2. Super-phosphate	0·0714	0·170	0·2414	1·3385	18·0

Percentage of total CaO, total P_2O_5 and available P_2O_5 in composting after 60 days of composting of Wheat straw

	Total CaO %	Total P_2O_5%	Available P_2O_5%
1. Control	1·89	0·5536	traces
2. Rock phosphate	2·80	0·9127	0·1912

Effect of rock phosphate (Trichnopoly nodules) and super-phosphate (1 mol H_2SO_4) on composting

Dung compost (24 kgms dung + 900 gms soil)

Moisture 71·7%

Analysis of dung—

	Dry basis	Wet basis	
Total carbon	= 29·25%	8·2778%	C/N ratio=17·2
Total nitrogen	= 1·70%	0·4811%	

Analysis of soil added—

Total carbon =0·435%

Total nitrogen=0·040%

(9 lbs of P_2O_5 added per ton of manure)

TABLE No. 2

Balance-sheet of Nitrogen in the composting of dung

	Initial			After 40 days				After 80 days			
	Total carbon %	Total nitrogen%	Total nitrogen in gms	Total carbon %	Total nitrogen%	Total nitrogen in gms	% increase in total nitrogen	Total carbon %	Total nitrogen%	Total nitrogen in gms	Decrease %
1. Control	25·9	1·55	115·82	15·53	1·890	119·1	2·85	13·61	1·613	109·17	13·52
2. Superphosphate	25·7	1·49	115·82	15·38	2·075	124·2	7·25	15·00	1·950	115·11	0·61
3. Rock phosphate (Trichnopoly)	25·8	1·50	115·82	15·00	1·940	121·7	5·09	13·77	1·750	105·17	9·19
4. Rock phosphate (Regd. No. 7391 II)	25·8	1·50	115·82	14·56	1·938	118·0	1·94	14·00	1·815	109·54	5·42

Balance-sheet of total Organic carbon in the composting of dung

	Initial		After 40 days			After 80 days		
	Total carbon in gms	C/N ratio	Total carbon in gms	Total carbon in gms oxidized	Total nitrogen increase in gms	Total carbon in gms	Total carbon oxidized in gms	Decrease in total nitrogen in gms
1. Control	1990·8	17·1	977·35	1013·5	3·3	845·2	1145·6	15·65
2. Superphosphate	1990·8	17·1	920·0	1070·8	8·4	885·5	1105·3	0·73
3. Rock phosphate (Trichnopoly)	1990·8	17·1	941·35	1049·4	5·9	827·5	1163·3	10·65
4. Rock phosphate	1990·8	17·1	885·9	1104·9	2·2	844·9	1145·9	6·28

Percentage of available Nitrogen after 40 days in composting of dung

	% of ammoniacal nitrogen	% nitrate nitrogen	% Total available	Total nitrogen %	% of total N i.e. $\frac{\text{available}}{\text{total}} \times 100$
1. Control	0·052	0 050	0·102	1·89	5·4
2. Super-phosphate	0·058	0·056	0·114	2·075	5·5

Percentage of total CaO, total P_2O_5 and available P_2O_5 in composts after 80 days of composting of dung

	Total CaO %	Total P_2O_5 %	Available P_2O_5 %
1. Control	2·3940	0·1730	0·0064
2. Rock phosphate	3·0564	0·3525	0·0176

Effect of rock phosphate (Trichnopoly) and super-phosphate (2 mol) H_2SO_4 on composting

Green Weeds

16 kgms green weeds+375 gms soil

Moisture=76·5%

Analysis of green weeds

	Dry basis	Wet basis	
Total carbon	31·15%	7·320%	C/N ratio = 12·7
Total nitrogen	2·45%	0·576%	

Analysis of soil added

Total carbon=0·435%
Total nitrogen=0·040%
(9 lbs of P_2O_5 added per ton of manure)

TABLE No. 3

Balance-sheet of nitrogen in composting of green weeds

	Initial			After 40 days			
	Total carbon %	Total nitrogen %	Total nitrogen in gms	Total carbon %	Total nitrogen %	Total nitrogen in gms	% decrease in total nitrogen
1. Control	31·15	2·45	88·2	8·05	0·70	33·08	56·80
2. Rock phosphate (dose 20 gms)	31·15	2·45	88·6	9·80	0·80	39·50	56·50
3. Rock phosphate (dose 40 gms)	31·15	2·45	88·7	9·32	1·00	39·48	55·50
			After 98 days				
4. Super-phosphate (dose 30 gms)	31·15	2·45	88·6	14·06	1·00	36·35	58·90
5. Super-phosphate (dose 60 gms)	31·15	2 45	88·8	10·40	1·05	38·11	57·08

Balance-sheet of total Organic carbon in the composting of green weeds

	Initial		After 40 days		
	Total carbon in gms	C/N ratio	Total carbon in gms	Total carbon in gms oxidized	Total nitrogen loss in gms
1. Control	1121·8	12·7	438·00	683·80	50·12
2. Rock phosphate (dose 20 gms)	1126·6	12·7	484·12	642·48	49·10
3. Rock phosphate (dose 40 gms)	1127·4	12·7	367·9	759·50	49·25
		After 98 days			
4. Super-phosphate (dose 30 gms)	1127·6	12·7	511·8	615·52	52·25
5. Super-phosphate (dose 60 gms)	1128·8	12·7	377·5	751·30	50·69

In the following experiments on composting of dung along with other phosphates, basic slag of Indian Steel Industry has also been utilised with beneficial results.

Effect of rock phosphate (Trichnopoly) mixture of rock phosphate and superphosphate and basic slag on composting of dung

32·4 lbs P_2N_5 added per ton of organic matter
Cowdung compost—24 kgms dung+500 gms soil

Total P_2O_5=6·70 %

Basic slag—Available P_2O_5=4·46%

Analysis of dung on oven-dry basis

Moisture—72·09%

Total carbon=18·84%
Total nitrogen= 1·04%
C/N=18·1

Analysis of soil added—

Total carbon=0·435%

Total nitrogen=0·040%

TABLE No. 4

Balance-sheet of Nitrogen in composting of dung

	Initial			After 45 days				After 110 day				After 170 days			
	Total carbon %	Total nitrogen %	Total nitrogen in gms	Total carbon %	Total nitrogen %	Total nitrogen in gms	% Increase in total nitrogen	Total carbon %	Total nitrogen %	Total nitrogen in gms	% increase in total nitrogen	Total carbon %	Total nitrogen %	Total nitrogen in gms	% increase in total nitrogen
Control	17·560	0·98	70·76	16·93	1·115	72·587	2·582	16·75	1·135	69·710	—1·483	16·72	1·138	69·700	— 1·30
Rock phosphate	16·900	0·97	70·76	15·75	1·180	74·804	5·715	15·16	1·163	73·770	+4·254	15·06	1·190	70·805	+ 0·06
,, +Super-phosphate	16·700	0·94	70·76	16·97	1·230	80·627	13·940	15·81	1·235	78·520	+10·96	15·50	1·250	78·850	+11·40
Basic slag	16·500	0·92	70·76	16·13	1·120	73·114	3·327	15·63	1·200	75·636	+ 6·89	14·66	1·230	76·610	+8·20

Balance-sheet of total Organic carbon in composting of dung

	Initial		After 45 days			After 110 days			After 170 days		
	Total carbon in gms	C/N ratio	Total carbon in gms	Total carbon oxidized in gms	Total nitrogen increased in gms	Total carbon in gms	Total carbon oxidized in gms	Total nitrogen increased in gms	Total carbon in gms	Total carbon oxidised in gms	Total nitrogen increased in gms
Control	1267·8	17·9	1102·1	165·7	1·827	1029·0	238·8	—1·050	1024·10	243·70	—1·060
Rock phosphate	1267·8	17·9	998·4	269·4	4·044	907·4	360·4	+3·010	896·07	371·73	+0·045
Rock phosphate + super-phosphate	1267·8	17·9	1112·4	155·4	9·867	1003·0	264·8	+7·760	977·80	290·00	+8·090
Basic slag	1267·8	17·9	1053·0	214·8	2·354	982·6	285·2	+4·876	913·10	345·70	+5·850

Percentage of available Nitrogen after 170 days in composting of dung

	% ammoniacal nitrogen	% nitrite nitrogen	% Total available	Total nitrogen %	$\frac{\text{Available} \times 100}{\text{Total}}$
1. Control	0·055	0·050	0·105	1·138	9·31
2. Rock phosphate+super-phosphate	0·065	0·063	0·128	1·250	10·24

The composts described in the foregoing pages were prepared in wooden boxes for obtaining quantitative results regarding the loss of carbon and increase of nitrogen.

Composting in pits.—We have also studied the composting of all kinds of waste vegetation and organic matter in a pit $14\frac{1}{2}' \times 10\frac{1}{2}' \times 1\frac{1}{2}'$. In this case the loss of carbon could not be determined quantitatively but the compost formed by mixing all types of organic matter with powdered phosphate rock after 30 days of composting gave the following analysis. As the compost heap received sunshine for over 10 hours daily the temperature of the heaps varied from 36°C—48°C.

Sample between 50—100 mesh

Analysis after 30 days on oven-dry basis

$$\left.\begin{array}{l}\text{Total carbon} = 20{\cdot}84\% \\ \text{Total nitrogen} = 1{\cdot}9\%\end{array}\right\} \text{C/N ratio} = 10{\cdot}9 \; .$$

Ammoniacal nitrogen = 0·0240%

Nitrate nitrogen = 0·0400%

Total available = 0·0640%

$$\frac{\text{Available} \times 100}{\text{Total}} = 3{\cdot}4$$

Total CaO = 4·410%

Total P_2O_5 = 2·682%

Available P_2O_5 (1% citric) acid) = 0·3708%

The following table gives the percentage of total carbon and nitrogen of composts taken from the pit after 60 days and 70 days repectively.

	I	II
Total carbon	15·1%	16·1%
Total nitrogen	1·80%	1·75%

It is interesting to note that a compost containing 1·9% total nitrogen with a C/N ratio of 11 is readily obtained in 30 days by mixing all types of organic matter. In the Indore method of composting of plant materials, the total nitrogen of the compost obtained is about 1%, whilst in our method with phosphate rocks, the total nitrogen is almost double.

DISCUSSION

The foregoing experimental results clearly show that there is an appreciable fixation of nitrogen when wheat straw or dung is composted in presence of calcium phosphate and no loss of nitrogen is observed even after 60 days in the wheat staw compost whilst in the dung compost which is richer in nitrogen there is a small loss after 80 days. Moreover the loss is appreciably less in presence of calcium phosphates than in the control sets without the addition of phosphate. On the whole super-phosphate or a mixture of super-phosphate and phosphate rock appears to be better than phosphate rock alone.

On the other hand, in the composting of green weeds and other organic matter very poor in lignin the loss of nitrogen is much greater. It appears therefore that materials containig more ligin produce a compost which suffers less loss of nitrogen then materials poor in the lignin. In most of our experiments

the temperature of the surrounding air was about 30°C. The temperature attained in our composts never exceeded 38°C whilst in the Indore method the temperature goes up to 63°C and hence there is more frequent loss of nitrogen in this method. Repeated stirring of the compost is of great value in avoiding the loss of nitrogen.

If powdered calcium phosphate or super-phosphate or basic slag is added to a green manure crop and ploughed in there is no doubt that marked nitrogen fixation takes place and the soil is enriched. But the nitrogen fixed is lost more readily than from systems like wheat straw or dung aided by calcium phosphate. It is clear therefore that for improving the humus capital of a soil, straw or dung aided by calcium phosphate is much better than green manures and phosphates.

The organic matter present in the soil or added to it or in compost heaps undergoes slow oxidation in the soil aided by sunlight, chemical catalysts, micro-organisms etc., and fixes atmospheric nitrogen and forms proteins in the process.

If we calculate the amount of nitrogen fixed in these composts per gram of carbon oxidized some interesting results are obtained. With wheat straw to which small amounts of good soil containing 0 25% nitrogen, 0·425% P_2O_5 and 3·4% CaO the efficiency of the fixation of nitrogen *i.e.*, the amount of nitrogen fixed in mgms per gram of carbon oxidized is only 0·35 in absence of phosphates whilst in presence of super-phosphate the efficiency of nitrogen fixation is 4·4. On the other hand when the same straw is mixed with large qauntities of the good soil as it happens when straw is ploughed in the soil, the efficiency of the nitrogen fixation reaches the high value 150 when the system received light and in absence of light the efficiency is 100. In the composting of cowdung with a soil containing 0·04% nitrogen, and 0·08% P_2O_5 and 10·0% CaO the efficiency of the nitrogen fixation in the composting process is approximately 5 in absence of phosphates and approximately 20 in presence of phosphates. When the same dung is ploughed in the soil or mixed with large amount of soil this efficiency of nitrogen fixation is much greater. Consequently from the economy point of view direct addition of plant materials or dung to the soil is certainly more profitable than the composting of such materials and the use of such composts. This point of view has been clearly emphasised by Dhar in his Presidential Address to the National Academy of Sciences, India in 1937. It is interesting to note that the C/N ratio of the composts obtained in presence of phophates is smaller than in the composts prepared without phosphates.

Under ordinary conditions, the proteins present or formed in nitrogen fixation undergo ammonification and nitrification which are also accelerated by light absorption and increase of temperature and form nitrate as in the following scheme :—

$$\text{Proteins} \longrightarrow \text{amino acid} \xrightarrow{+O_2} NH_4 \text{ compounds} \longrightarrow NO_2 \xrightarrow{+O_2} NO_3 \quad (+O_3)$$

In these series of reactions the unstable substance, ammonium nitrite is formed and it decomposes according to the equation :—

$$NH_4NO_2 = N_2 + 2H_2O + 718 \text{KCal}.$$

Hence along with nitrogen fixation and formation of proteins due to the oxidation of energy materials both in compost heaps or in soils, ammonification and nitrification which oppose the increase of proteins in the soil or in compost

heaps take place and thus the amount of protein remaining in the soil or in compost heaps tend to decrease. Hence the apparent efficiency of nitrogen fixation *i.e.*, the amount of nitrogen fixed per gram of carbon of the organic matter oxidized falls off when ammonification and nitrification take place. But in presence of large amounts of phosphate in the system more or less stable phosphoproteins are formed by the combination of proteins and phosphorus compounds. These compounds seem to resist ammonification, nitrification and loss of nitrogen better than proteins alone. This appears to be an important reason why the efficiency of nitrogen fixation in soils or in compost heaps appears to be larger in presence of increasing quantities of phosphates.

Hence, it is clear that phosphates when added along with organic matter in compost heaps plays a dual role, *firstly* it helps in the fixation of atmospherie nitrogen as the carbon of the organic matter undergoes oxidation and *secondly* it stabilises the nitrogenous compounds present or formed in the compost. Further it appears that tne lignin content of the material to be composted is also of great importance in these processes as the lignin is less liable to be oxidized than the cellulose and other constituents and thus protects the proteins and other nitrogenous compounds from rapid nitrification and consequent loss as gaseous nitrogen.

When ammonium salts or urea are used in helping the compost formation, there is always the possibility of the formation of the unstable compound ammonium nitrite due to nitrification and consequent loss of nitrogen as gas. Thus in the Adco process and in other methods of composting with the addition of ammonium salts or urea, marked loss of nitrogen has been reported.

It is well-known that green manures are used in improving the nitrogen status of a soil rather than its humus content. Moreover Broadbent[2] has reported that ploughing in of Sudan grass as a green manure leads to the loss of soil humus. Similarly the following results have been reported in the green manure experiments in Woburn :—

		Original soil 1892	Mustard soil %	Taras soil %
Moisture		...	7·17	10·75
In soil dried at 100°C	Organic matter	3·11	2·48	2·61
	Nitrogen	0·13	0·080	0·084

In many of our[1] recent experiments on nitrogen fixation using soils rich in calcium phosphate and straw or *Gur* (sugar candy) as energy material we have observed a marked loss of the carbon of the humus along with the oxidation of the added carbonaceous compounds as in the following tables :—

Analysis of the soil used—

Total carbon =1·5980%

Total nitrogen =0·2075%

C/N ratio =7·7

Total P_2O_5 (HCl soluble) %= 0·4178

Total CaO „ „ = 3·40

The oxidation of the carbon of the humus of the above soil are as follows :—

	Total carbon %	
	Initial	After 80 days
1. 200 gms soil+2 gms wheat straw	1·9673	0·9734
2. 200 gms soil+2 gms wheat straw + 0·25% P_2O_5 as Na_2HPO_4 12 H_2O	1·9510	0·7466
3. 200 gms soil+4 gms wheat straw	2·3343	1·3140
4. 200 gms soil+4 gms wheat straw + 0·25% P_2O_5 as Na_2HPO_4 12 H_2O	2·3120	1 0270
5. 200 gms soil+2 gms *Gur*	1·9450	0·9328
6. 200 gms soil+2 gms *Gur* + 0·25% P_2O_5 as Na_2HPO_4 12H_2O	1·9100	0·7602
7. 200 gms soil+4 gms *Gur*	2·2754	0·9560
8. 200 gms soil+4 gms *Gur* + 0·25%P_2O_5 as Na_2HPO_4 12 H_2O	2·2620	0·7488

Moreover we have observed that when a mixture of straw and coal or lignite is added to soil and allowed to oxidize, the straw undergoes oxidation at a faster rate than in the absence of coal.

There is no doubt that the ploughing in of green manures, Sudan grass, etc., which undergoes fairly quick oxidation in the soil makes the soil more porous and thus the organic matter or humus present in the soil or added to it are liable to be oxidized more readily than in the absence of the green manures. By the ploughing in of the green manures specially in presence of calcium phosphate there is appreciable increase in nitrogen by fixation, and soil fertility which however is lost fairly readily because the humus formed by the addition of easily oxidizable carbohydrates, molasses, celluloses etc., undergo oxidation more readily in the soil than the humus rich in lignin.

Four factors are vitally important in the oxidation of organic matter when added to the soil or in compost heaps (*i*) pH of the soil or the heap, alkali always helps oxidation and acid retards it (*ii*) increase of temperature is a vital factor in increasing oxidation (*iii*) Light is also important in helping oxidation (*iv*) lignin being much more resistant towards oxidation, cellulosic materials rich in lignin like sawdust, dry wood, etc., do not oxidize readily in the compost heap or in the soil. Fresh organic matter like green leaves, fresh grass, etc., contain soluble carbohydrates and when added to the soil are readily oxidized but being poor in lignin very little humus is left in the soil. For nitrogen fixation these materials are more quick in their action than straw or sawdust. These latter substances are useful in increasing the humus and stability of the soil. If we are looking for materials to creat humus in the soil, green leaves, grass, sunnhemp or other legumes are less suitable than staw or sawdust or even dung.

On the other hand, if one is looking for a quick acting organic manure, a mixture of phosphate rock or basic slag with green grass, legumes, green leaves, etc., should be profitable after a time interval of 4-6 months in Europe and about 1-3 months in India according to the amounts of organic matter ploughed in.

The average temperature of Rothamsted is about 8°C, whilst at Versailles near Paris the temperature is about 9—10°C whilst at Upsalla it is 5°C. At Allahabad the average temperature is about 26°C, hence the velocity of the oxidation of organic matter added to the soil is about 3–4 times higher in India than in the places in Europe mentioned above. In Woburn (average temperature

8°C) green manuring has been studied but as the soils were acidic and very low in total and exchangeable calcium, no beneficial results were obtained. But in other parts of England in many cases beneficial results with green manuring has been report. The ploughing in of organic matter like grass, legumes, leaves, etc., should always be accompanied by the addition of a good dose powdered soft phosphates rock or basic slag specially in temperate countries where the soils have a tendency to be acidic. The failure of the Woburn experiments with green manuring may be due partially to the addition of super-phosphate which is distinctly acidic and retards the oxidation of organic matter immediately after adding it to the soil. The following lines from Colling's[3] book show that green manuring has been profitable in many parts of U. S. A. specially with artificials.

"Many agricultural experimental stations have shown that incorporation of green manures in the soil, in addition to a complete fertilizer results in an increase in the yields of succeding crops. Most soils are benefitted by the addition of suitable organic matter regardless of the quantity they contain. Johnson at the Virginia Truck Experimental Station, found that when a ton of a 6-4-8 fertilizer was applied, the average yield of potato was 155 bushels but when a green manure crop was turned under previous to the addition of fertilizer, the average yield was raised to 232 bushels."

Hence from our experiments recorded in the foregoing pages and the above discussions it is clear that for the preparation of stable composts both calcium phosphate and lignin are useful and such composts can be prepared from straw or dung within a month or 40 days when the air temperature is 30°C. Materials poor in lignin should be reinforced with calcium phosphate and ploughed in the soil for fixing atmospheric nitrogen and increasing soil fertility. If composts have to be prepared with these materials 20—30 days would be quite adequate for this purpose in India in the summer or autumn.

By using phosphate along with organic matter, composts containing 2% total nitrogen can be prepared even in 30 days when the air temperature is 30°C.

On carefully reading the paper of Hutchinton, and Richards[6], it appears that their views regarding the mechanism of compost formationfrom straw and all their speculations regarding the nitrogen contents of compo t and dung are not sound. The following processes take place when plant materials undergo oxidation in contact with air with or without nitrogenous fertilizers or urine :—

(1) The carbohydrates *i.e.*, cellulose, lignin, etc. being in larger amounts undergo slow oxidation under the influence of chemical catalysts, surface, light and micro-organisms into carbon dioxide and water. Consequently the percentage of total nitrogen in the system tends to increase with the progress of composting. Under ordinary circumstances the total amount of nitrogen present in the compost heap may be the same or less but in presence of phosphates there is appreciable nitrogen fixation and increase of total nitrogen. All natural substances like dung, straw, leaves, etc., contain calcium phosphate and hence under favourable conditions if the system is well stirred and the temperature does not rise much there may be a fixation of atmospheric nitrogen even in the absence of added phosphates, but certainly in presence of added calcium phosphate there is a chance of greater fixation of atmospheric nitrogen. But if the nitrogen content of the materials is high or nitrogenous substances like urine, ammonium salts along with potash and phosphate are added as is done in composting in temperate countries there is usually loss in nitrogen as is recorded in the following table from Collings.

TABLE No. 30

Page 136 From "Commercial Fertilizers" by Collings

Decomposition of organic constituents during composting in gms per 100 G of original material*

Constituent analysed	Oat straw+Inorganic salts			Oat straw+Clover hay			Cow manure			Peat+Timothy hay			Cornstalks+Inorganic salts			Leaves+Timothy hay		
	At start	At end 110 days	Loss—or gain+ %	At start	At end 110 days	Loss—or gain+ %	At start	At end 110 days	Loss—or gain+ %	At start	At end 100 days	Loss—or gain+ %	At start	At end 110 days	%	At start	At end 110 days	%
Total material	100	44	56	100	34	66	100	47	53	100	62	38	100	49	51	100	38	62
Ether-soluble portion	2·4	0·34	—86	2·4	0·23	—91	·6	0·23	—86	1·3	0·17	—86	1·40	0·13	—91	2·8	0·76	—73
Water soluble organic matter	9·0	2·34	—74	10·50	4·6	—56	9·0	3·41	—62	5·0	2·66	—46	15·5	2·66	—83	11·7	2·25	—81
Hemi-celluloses	16·5	—5·55	—66	15·5	4·17	—73	15·7	2·82	—82	10·5	4·17	—60	20·0	3·69	— 81	13·0	3·48	—73
Cellulose	33·0	4·19	—87	30·8	5·10	—83	18·9	1·60	—92	7·8	0·88	—90	27·4	3·94	— 86	15·7	1·82	—88
Lignin	13·4	11·55	—14	13·6	8·00	—41	20·8	11·00	—47	38·0	2·40	—38	9·5	10·12	+ 7	25·1	11·30	—55
Crude protein	1·7	5·11	+197	3·8	4·05	+ 7	9·1	8·25	—10	14·5	12·15	—16	2·0	4·9	+147	5·5	3·76	—32
Ash	5·5	9·65	+75	5·77	5·77	+ 4	17·3	17·38	0	10·7	12·91	+21	6·3	14·05	—124	10·2	10·50	+3
Total N	1·36‡	1·03	—23	1·24	0·85	—26	2·16	1·44	—33	2·38	2·00	—13	1·28	1·09	—15	1·13	0·70	—38
Total N†	—	2·34	—	—	2·50	—	—	3·07	—	—	3·22	—	—	2·23	—	—	1·84	—

* On basis of 100 G. of original material.

† % on end product.

‡ Includes 0·7 % N added within organic salts.

The foregoing results clearly show that the total nitrogen in the end product of the compost may be as high as 3·07 to 3·22% depending on the richness in protein and total nitrogen in the starting materials for composting The total nitrogen in a compost produced certainlv depends on the total nitrogen present in the material plus the nitrogen added. In all our experiments on composting with dung which is richer in nitrogen than straw the former when composted has been found to be richer in nitrogen than the latter.

All the speculations, discussions and calculations in Hutchinson and Richards[6] paper in trying to explain whv 2% nitrogen is the limiting amount in composts and in animals dungs are not useful, because composts containing 3·22% or more nitrogen can be prepared. The process of composting is controlled by the total nitrogen content of the system, by the amount of lignin present, the temperature and the calcium phosphate content.

Moreover Rothamsted[8] results show that dungs obtained from feeding root and hay contain 0·577% nitrogen (2·02% N on drv basis) whilst the dung obtained from feeding cake contains 0·716% nitrogen (2·506% N on dry basis). Hence on dry basis the nitrogen contents become much greater than 2% in the cake fed dung. It is clear that the nitrogen status of a dung depends on the nitrogen content of the feed.

From our experiments we have come to the conclusion that in composting plant materials, the oxidation of the carbohvdrates and the energy materials seem to be an autocatalytic process in which the breakdown of the energy material is accelerated with time up to a limiting value causing a marked increase in the temperature of the svstem. The oxidation of the energy materials by air has to be just initiated and then the energy produced maintains a reaction at an increasing speed up to a limiting value and hence the minimum amount of nitrogen needed for composting of the energy materials like straw, farmvard manure in soils has no fixed value but can be exceedingly small depending on the experimental conditions and that is why different values of nitrogen factor have been recorded in the literature.

SUMMARY

1. The aim of composting is to save the nitrogen, potash phosphate and trace elements present in natural organic substances with a C/N ratio much greater than 10 and to produce a material having a C/N ratio of about 10.

2. Experiments on composting carried on in different countries show that not only the nitrogen added in the available condition as nitrogenous substances in composting is lost but the nitrogen present in the organic matter may also be partially lost.

3. This loss of nitrogen is due to the high temperature prevailing in the compost pits and acidity produced during the decomposition of the organic matter in pits or heaps. These lead to the rapid decomposition of the unstable substance ammonium nitrite formed in the nitrification of nitrogenous compounds according to the following equation :—

$$NH_2NO_2 = N_2 + 2H_2O + 718 \text{ KCl}$$

4. The loss of nitrogen can be minimised if the temperature of the system and its acidity are not allowed to rise much. This can be achieved by repeated

stirring of the materials of the compost heap and thus dissipating the heat produced in the oxidation of organic matter.

5. An elegant method of composting has been worked out by simply adding a small amount of soil to the organic matter to be composted. Calcium phosphate enhance the nitrogen fixation by organic matter and hence it is helpful in composting of plant materials when mixed in a finely powdered state and calcium phosphates or super-phosphates should always be used in composting.

6. The percentage increase of nitrogen in the composting of wheat straw without phosphate, treated with rock phosphate and super-phosphate at the rate of 9 lbs P_2O_5 per ton of organic matter were found to be 0·95, 8·9 and 14·5 respectively after 60 days.

7. In composting of a dung containing 1·7% total nitrogen, the percentage increase in the nitrogen were found to be 2·85, 5·09, 1·94 and 7·25 respectively with no phosphate, with two varieties of rock phosphate and super-phosphate after 40 days days of composting ; whilst after 80 days there is a loss of nitrogen due to the high nitrogen content of the dung compost. In composting an ordinary dung containing 1·049 total nitrogen the percentage increase of nitrogen after 45 days were observed as 2·58 without phosphate, 5·7 with rock phosphate, 13·94 with a mixture of rock phosphate and super-phosphate and 3·3 with basis slag ; whilst after 110 days the values observed are loss of 1·48% of nitrogen without phosphate and increase of 4·25, 10·96 and 6·89% respectively with rock phosphate, mixture of rock phosphate and super-phosphate and basis slag respectively.

8. The maximum percentage of total nitrogen observed in the composts are 2·075 with good quality dung and super-phosphate, and 1·235 with ordinary dung and a mixture of rock phosphate and super-phosphate. In the composting of straw mixed with super-phosphate the value is 1·338 whilst with different types of organic matter and rock phosphate in the pit compost it is 1·9% of total nitrogen.

9. In the composting of fresh green weeds there is a marked loss of nitrogen as they are poor in lignin.

10. In presence of phosphates the proteins that are present in the soil humus are likely to be stabilised by the formation of complex compounds with the combination of proteins and phosphates. These compounds seem to resist ammonification, nitrification and consequent loss of nitrogen better than the proteins as such. This appears to be an important reason why the efficiency of nitrogen fixation in soils or in composts treated with phosphates are greater than those with no phosphate. The efficiency of nitrogen fixation *i e.*, the amount of nitrogen fixed in mgms per gram of carbon oxidized in the composts of dung is 20 in presence of phosphates and 5 in absence of phosphates. In the composting of straw the efficiency is 4·4 in presence of phosphate and 0·35 in absence of phosphates.

The C/N ratio of composts prepared by adding calcium phosphates is smaller than that obtained without phosphate.

When these organic substances are ploughed in the soil, the efficiency of nitrogen fixation is greatly increased and hence direct ploughing in of plant materials or other organic substances in the soil is more profitable than their composting and application as composts.

REFERENCES

1. Bose, S. M., 1953. *D. Phil. Thesis in Chemistry, Allahabad University.*
2. Broadbent, F. E. and Norman, A. G., 1947-48. *Proc. Soil Sci. Soc. Amer.*, **11**, 264 and **12**, 246.
3. Collings, G. H., 1941. "Commercial Fertilizers, 4th Edition," p. 436.
4. Dhar, N. R., 1952. *The Nat. Acad. Sci. (India), Business Matters*, p. 15.
5. Ghildyal, B. N. P., 1950. *D. Phil Thesis in Chemistry, Allahabad University.*
6. Hutchinson, H. B. and Richards, E. H., 1921, *C. J. Min. Agric.* **28**, 398.
7. Howard, A. and Wad, Y. D. 1931, "The Waste Products of Agriculture"
8. Russell, E. J. and Voeleker, J. A., 1936. "Fifty years of field Emperiments."

THE ROLE OF LEGUMINOUS PLANTS IN SOIL FERTILITY AND CROP PRODUCTION WITH SPECIAL REFERENCE TO MADRAS STATE

By

S. VARADARAJAN *and* T. RAJAGOPALA IYENGAR

Agricultural Research Institute, Coimbatore

Communicated by Prof. S. Ghosh

(*Received on 12th November 1954*)

INTRDOUCTION

The low state of soil fertility in many parts of India is an inherent factor that stands in the way of crop production to a great extent. Most of the soils are poor in nitrogen and deficient in organic matter and phosphates. This is especially true, in the case of soils of the Madras State. This fact had been stressed in the Report of the Royal Commission on Agriculture (1928) as follows :—

"Soils of Madras, Mysore, S. E. Bombay, Hyderabad, Central Provinces, Orissa, Chota Nagpur and south of Bengal are as a rule deficient in nitrogen, phosphoric acid and humus, but potash and lime are generally deemed sufficient."

With the system of agriculture obtaining in the State and the condition of soils which have been bearing crops for ages past, it is clear that the soils cannot be but poor. It is well-known that crop production entirely depends upon the soil and its fertility. The dynamic nature of the soil with its ever changing physical, chemical and biological properties, has come to be fully realised. Even under the best systems of farming cultivated soils do not maintain their high level of fertility for any length of time and therefore the soil fertility is prone to decline.

In the agriculture of yore the only way known for increasing soil fertility was by pulverizing the soil with manual labour to produce a good physical condition for maxium moisture retentivity. Later, with the harnessing of animal power to till the land, the knowledge of the usefulness of cattle manure as the best ingredient to increase the productive capacity of soils was also gained. The beneficial effect of cattle manure and other organic manures cannot be ignored even today despite the wide use of chemical fertilizers for manuring of crops in recent times. It is easy to understand that most of our soils are poor in retaining moisture due to paucity or lack of humus. Moreover, over a large area of the State the rains are not well distributed throughout the year or even during a crop season. This uneven distribution of the rains has made the *ryots* to overcome the situation by giving frequent intercultivation so that a good tilth may be obtained which will aid in minimising or preventing the loss of soil moisture.

However, this is a most laborious and not quite an effective method. The most effective method of improving the physical properties of the soil is by the application of organic manures like cattle manure, compost, and green manures.

The quantity of cattle manure available in the country is not sufficient for all the cultivated lands and crops. There is a limitation to the production of compost also. Though artificial fertilizers have come into vogue, they cannot be used without sufficient humus in the soil. Thus it would appear that green material from plants would be the ideal to provide unrestricted supply of organic matter. This is not, however, far from the truth. For this purpose and for supply of N as well to the soil the leguminous plants rank foremost and score over others, providing thereby the "key to soil fertility."

There is well founded evidence that agriculture has been practiced for more than six thousand years and it is certain that the farmers of yore understood the important part which the legumes played in maintaining and improving soil fertility. From such early times the importance of the legume is known to the regions of the cradle of civilization such as the South-Western Asia, Swiss Lake Dwellers of the Stone and Bronze Ages, the Greeks, the Romans, the Indians and Colonial Agriculture of the New World. Early in the 19th century, with the recognition and development of modern agricultural science, more information began to accumulate. In 1813 Sir Humphy Davy mentioned in his book on Agricultural Chemistry that "Peas and beans in all instances seem well adapted to prepare the ground for wheat . . . " Boussingault in his classical studies confirmed these findings and suggested that leguminous plants assimilate nitrogen from the atmosphere.

The presence of nodules on the roots of legumes was known long before their significance was recognised and Lachmann observed in 1858 that mobile bacteria caused the formation of nodules and that they are responsible for nitrogen fixation.

Atwater and Woods recognised in 1884 the possibility that both plants and bacteria are factors in the process of fixation of nitrogen. Hellriegal and Wilfarth proved conclusively that the bacteria within the nodules have the power of taking the free nitrogen from the soil air and convert it into a form suitable for plants. In 1888 Beijerinck isolated the causative organism in pure culture and later the mechanism of the root infection was studied by Prazmowski in detail. The amount of nitrogen fixed was worked out by Schloesing and Laurent and their findings were confirmed by several workers, chief among them being Virtanen. Fred, Baldwin and McCoy studied the strain variations of the bacteria as influencing nitrogen fixation. Thornton of England pointed out the necessity of efficient cultures to bring about the improvement both in quality and yield of legumes.

The symbiotic nitrogen fixation is now well recognized as of great economic importance. The amount of nitrogen added to the soil by a leguminous crop will be enormous especially in a soil poor in nitrogen. Warrington demonstrated that about 350 lb of nitrogen per acre could be obtained by growing inoculated clover. Subsequent work all over the world has proved the large gain in soil nitrogen due to growth of leguminous plants in the presence of specific bacteria.

The leguminous plants are important in building up soil fertility in two ways, namely, in providing organic matter and augmenting the nitrogen supply of the soil by fixing atmospheric nitrogon. Apart from this, the legumes, by

virtue of their roots in most cases with high acidity, are able to absorb mineral nutrients from the deeper layers of the soil and render them available to the suceeeding crops.

Studies on legumes of economic importance have been carried out in the State with reference to the following aspects :

1. Leguminous crops as green manure.
2. ,, in crop rotation.
3. ,, in soil reclamation.
4. ,, in associated growth with cereals.

1. *Leguminous plants as green manure* :—When a large quantity of green material is applied to the soil, the plant nutrients such as nitrogen, phosphoric acid and potash contained in them are also added to it. If a green manure crop is raised and turned under in situ, the plant nutrients already present in the soil is transformed into more easily available forms. Sometimes such crops may bring up the plant nutrients from the deeper layers and make them available to shallow rooted crops. But when green manure crops belonging to the *leguminacea* they provide additional nitrogen to the succeeding crops by virtue of their capacity to fix in their tissues atmospheric nitrogen. Where facilities for irrigation exist such legumes can be raised easily. Their nitrogen fixing ability can be increased by inoculating the seeds with the right type and strain of the root nodule bacterial cultures. Better nitrogen fixation is possible if super-phosphate is also applied to the crop at the time of sowing.

In a trial conducted at the Central Farm, Coimbatore it was found that the total nitrogen content of the soil increased from 10 to 20% in cluster beans; red gram and sunnhemp plots. By growing a legume specifically for green manure purpose over a number of years, it was found that the nitrogen fixed from the air ranged from 75 to 130 lb per acre. The soil nitrogen increased from 34 to 52 % over the control and the yield of paddy from 190 to 207% for grain and 302 to 417% for straw as can be seen from the table below :—

Yield of green matter, nitrogen added to the soil and the yield of paddy grain and straw due to some common green manure crop

Name of the crop	Green matter per acre lb	Nitrogen added per acre lb	Yield of paddy Grain lb	Yield of paddy Straw lb	% increase over no manure Grain	% increase over no manure Straw
Dhaincha	21,131	133	2626	7311	207	417
Sunnhemp	27,790	134	3467	6554	198	374
Pillipesara	22,337	102	3626	6415	207	366
Cowpea	21,055	74	3327	5299	190	302
Control	—	—	1753	1753	—	—

In practice, it may not be possible to raise green manure over a large area exclusively for the purpose of turning them under owing to the lack of adequate irrigation facilities and non-availability of seeds in required amounts. The best

plan under such circumstances would be to distribute the green material obtained from one acre to four or five acres. By manuring in this way an increase from 30 to 50% in the yield of paddy has been obtained in the several Agricultural Research Stations of the State.

Even along the bunds of paddy fields leguminous plants can be raised and in this *Sesbania speciosa* has proved to the best. In waste lands, along roads and ditches, tank bunds, etc., *Glivicidia maculata* can be raised which would supply green leaves for manuring paddy crops.

2. *Legumes in crop rotation* —It has been known for a long time that a crop succeeding a legume did well. In most systems of agriculture where a rotation is possible legumes are fitted in. In the Madras State crops such as Bengal gram, cowpea, horse gram, lab-lab, ground nut etc., are rotated with cereals. There are evidences to show in many instances that the succeeding cereal crop following a legume crop benefitted to a great extent. In Hebbal Farm in Mysore, the yield of ragi (*Eleucine coracana*), it is reported, has been increased by about 30% when it is grown in rotation with ground nut. In another experiment conducted at the Agricultural Research Station, Tindivanam (1952) cholam, varagu and cumbu grown in rotation with ground nut, have recorded the following average increase in yields over the pure crops grown without rotation.

Percentage increase in yield of cereals following ground nut
Average of three seasons.

	Bunch series		Spreading
	%		%
Cholam after ground nut	124·3		85.4
Cumbu after ground nut	48·8		51·6
Varagu after ground nut	119·4	lb	12·0

Note :—Normal yield of cholam 600
,, cumbu 300
,, varagu 300

This is just an instance of the usefulness of legume in increasing the productivity of crops.

The effect of a legume in the rotatation on the soil and on the succeeding crop is a resultant of a host of fatcors such as the the extent of water supply, the chemical composition of the soil, especially in regard to its nitrogen, phosphoric acid, lime and potash contents, besides the climatic factors and the nature of legumes grown. The presence or absence of the specific rhizobia also plays a part. Acharya *et al* (1952) have reported from their experiments conducted for over a decade at the Indian Agricultural Research Institute that *berseen* rotated with *wheat* and *cowpea* showed significantly higher amounts of nitrogen and organic matter when the *berseem* crop was adequately manured with phosphates. They found vigorous microbial activity and higher microbial population in plots manured with phosphates. Ammonification, nitrification and nitrogen fixation were also greater in such plots.

In a recent experiment which is in the first year of trials at the Central Farm, Coimbatore, phosphate application to a leguminous green manure crop (*Dhaincha*) has given increased yield of green matter as the data given below would reveal.

Yield of Dhaincha grown with and without phosphate application

Treatment	Moisture at harvest %	Yield of green matter lb	Increase due to P_2O_5%
Dhaincha without P_2O_5	64·72	11,123	—
Dhaincha with 30 lb P_2O_5 per acre	64·45	16,732	50·42

Parr and Bose have also stressed the importance of this aspect of building up soil fertility very well.

3. *Soil reclamation and legumes.*—Under reclamation we may classify the soils into two categories, namely (1) reclamation of saline or alkaline soils, and (2) reclamation of marginal lands.

In the case of reclamation of alkaline soils actual trials conducted at Mettumarudur in the Kattalai high level channel ayacut in Tiruchirapalli district, a crop of *dhaincha* raised in the lands after the preliminary correction of soil alkalinity using gypsum as an amendment, established quite well, contributing to the improvement of soil fertility and production of good crop of paddy with a high yield of 3000 lb per acre at the end of the third year.

For improving the productive capacity of marginal lands of the State with low rainfall of 20 to 30 inches per annum, growing of a leguminous crop fertilized with phosphate was found beneficial. For instance, in an experiment conducted at Koilpatti (Tirunelveli district) it was found that when a legume was raised with the application of phosphates and ploughed in, it provided nitrogen, organic matter and phosphates, in which the soil was deficient. The fertility of the soil was built up in course of three years and the soil which was not able to support a grain crop improved in fertility and yielded a fairly good crop of cereal.

There is yet another aspect, namely, that of conservation. Maintenance of organic matter has a direct influence on structure and soil moisture, which in turn govern the vegetation necessary for prevention of erosion by run off.

A huge programme for land improvement in Damodar Valley by cultivation of legumes as *dhaincha* and *sunnhemp* has already been in progress since 1951.

4. *Legumes in association with cereals.*—The growing of legumes in assocation with cereals has been found to be advantageous. In a rich soil the response may not be quite marked ; but in poor soils it may be quite patent. Even in fairly rich soils the growing of cereals and pulses together has been found beneficial. When thickly grown cereals are cultivated in association with a legume the latter has to derive its nitrogen nutrition mostly from the atmosphere. The depletion of soil nitrogen which would otherwise occur when cereals are grown alone is also prevented by this associated growth. Thus simultaneously a cereal as well as a pulse crop could be harvested, and in places where crops can be raised in this

manner, it will provide the farmer with carbohydrates and proteins for this food requirement as well as for his cattle. It has has been shown by many workers that the growth as well as the protein of certain cereals increased when grown in association with a suitable type of legume.

From trials conducted for several years in the State, it was established that for the slow growing pulse the ratio of one pulse to three of cereal and for others growing in equal proportion was the best to give satisfactory results.

When, the pulse crops were inoculated with the suitable rhizobia there was also an increase in yield from 10 to 30% over those grown without inoculation.

The associated growth of legumes and cereals is equally of great importance for improving marginal lands especially in areas of scanty rainfall to ensure some return to the former from either of the crops.

INCREASING THE EFFICIENCY OF NITROGEN FIXATION IN SOILS BY GROWING INOCULATED LEGUMES

It has been clearly established that the leguminous plants when inoculated with appropriate rhizobia grow well and enrich the soil. Numerous studies have been made of strain variations in bacteria which influence nitrogen fixation. One single strain of root nodule bacteria cannot infect and form nodules on all leguminous plants. There is a definite host specificity which is characteristic of eac strain. Of late, these bacteria have been classified into six or seven broad groups. Within each species there are various strains which differ in their nitrogen fixing ability. These factors make it imperative to explore for more and more efficient strains of organisms for inoculation of the leguminous crops in the different regions and soil types. There is thus a necessity to maintain a stock of efficient cultures for inoculation for the commonly cultivated legumes in the various part of the country. An organization on a wide scale for the isolation, maintenance and distribution of these efficient cultures to the farmers as in the advanced countries like U.S.A., England and Australia, is a long felt need for improvement of our agriculture.

THE FUTURE OF LEGUMINOUS CROPS IN OUR AGRICULTURE

Legumes are one of the largest groups of plants and being so important from the point of view of nitrogen economy of our agriculture, efforts should be made to include them more extensively and intensively in any system of cultivation. The number of species under cultivation is insignificantly small. Because of their value as food for man and animals and of their intrinsic value in agriculture, they have to be studied in greater detail in the future. This would serve as a potent source of improving our much depleted soil fertility with consequent increase in production. This naturally involves the study of (1) introduction and acclimatization of newer and better types of legumes suitable to different locatities, (2) soil condition in relations to nitrogen fixation, (3) bacteria in relation to host specificity and page relationship, and (4) relationship, of "activators" with reference to efficiency of strains.

In fine, the economic importance of legumes in any system of agriculture being so great, it needs exploitation on a greater scale by the chemists, botainsts and agronomists on all fronts particularly with reference to the biological, chemical and agronomical aspects.

ACKNOWLEDGMENT

The authors are thankful to the Director of Agriculture, Madras for the kind permission accorded to publish this paper.

BIBLIOGRAPHY

1. Acharya, C. N. (1952). Influence of legume in crop rotation on the Soil, Science and Culture, Vol. 18, No. 6, 280-287.

2. Allen, E. K. and Allen, O. N. (1950). Biochemical and symbiotic properties of the rhizobia, *Bact. Revs.*, **14** : 273-330.

3. Allison, F. E. and Ludwig, C. A. (1934). The cause of decreased nodule formation on legumes supplied with abundance combined nitrogen, *Soil Sci.*, **37** : 431-443.

4. Celino, M. S. (1950). *J. Soil Science Soc.*, Phillipines Vol. I, No. 2, 120-123.

5. Chen, H. K. and Thornton, H. G. (1940). The structure of "ineffective" nodules and its influence on nitrogen fixation, *Proc. Roy. London, B*, **129**: 208-229.

6. De Fellner, C. (1953) World Crops, Vol. V, No., 8, 318-320.

7. Desai, S. V. and Sen, A. (1942). Science and Culture, **17**, 323.

8. Dewan, M. C. (1953). Science and Culture, Vol. 18, No. 10, 476-482.

9. Fred, E. B., Baldwin, I. L. and McCoy, E. (1932). Root nodule bacteria and leguminous plants, University of Wisconsin Press, Madison Wis.

10. Government Agricultural Chemist—Unpublished data.

11. Khan, A. R. (1952). Indian Farming, Vol. II, No. 3, 8.

12. Lohnis F. (1926). Effect of growing legumes upon succeeding crops-- *Soil Sci.*, **22** : 355-389.

13. Narasinga Rao, M. B. V. (1952). The Madras Agri. J. XXXIX, No. 3 65-72.

14. Narayana G. V. (1952). Ibid., XXXIX, No. 5, 317-341.

15. Parr, C. H. and Bose, R. D. (1944). Indian Farming, Vol. II, No. 4 156-162.

16. Do. (1945)— Ibid., Vol. VI., No. 5, 201-208.

17. Do. (1947)— Ibid., Vol. VIII, No. 6, 267-275.

18. Parr, C. H. and Sen, S. (1948)— Ibid., Vol. IX, No. 6, 227-238.

19. Raju, M. S. (1953)--Legume inoculation, *Madras Agric. J.*, Vol. XL, No. 11, 499-502.

20. Report of the Royal Commission on Agriculture in India (1928)--Govt. Publication, New Delhi.

21. Varadarajan, S. (1948--Legumes and increased crop production, *Madras* Agric. J. Vol. XXXV, 11, 321-324.

22. U. S. Dept. of Agri. Year Book of Agriculture (1943-47).

LIQUID AMMONIA AS A FERTILIZER—SOME SOIL STUDIES ON NITROGEN TRANSFORMATIONS

By

B. V. VENKATARAO *and* S. V. GOVINDARAJAN

Department of Agriculture, Bangalore

Communicated by Prof. S. Ghosh

(Received on 14th December, 1954)

In recent years anhydrous liquid ammonia is being increasingly used as a nitrogenous fertilizers for crops in the United States of America and in other countries on the Continent. An extensive literature [1,2,4,5,7] has accumulated on its usage and techniques of application. It is a nitrogenous material containing as much as 82% nitrogen and contains a higher percentage of nitrogen than any other fertilizer material and is over four times as concentrated as ammonium sulphate, the commonly used nitrogenous fertilizer.

Use of ammonia directly as a fertilizer avoids the need for sulphur used in sulphuric acid in the manufacture of solid ammonium sulphate, and if the former can prove as effective as the usually used solid fertilizers, it would be a great advantage from the point of national economy. With the object of ascertaining if ammonia could be used efficiently as a fertilizer under Indian conditions in place of ammonium sulphate, certain studies have been undertaken by us, and the result of preliminary studies on the transformation of ammoniacal nitrogen after injection of liquid ammonia into the soil are reported in this paper.

A suitable equipment was devised at the Mysore Agricultural College, Hebbal, to inject the ammonia contained in steel cylinders into the soil. The mechanism consists of a steel pipe attached to the rear of a plough share and connected to the ammonia cylinder by means of hose pipe. The cylinder is mounted on a chassis provided with wheels and drawn by bullocks. When the plough is held pressed into the soil and worked, ammonia gas is injected into the soil by means of the steel tube fitted to the back of the plough point. As such the ammonia gets applied into the soil at a depth of 4 to 6 inches and gets covered over with soil as the plough progresses.

The experiments were begun on 17-3-1954 and liquid ammonia was injected in measured doses into the soil and samples of soil were collected from the furrows immediately after injection and at intervals. Soil cores, without disturbing the soil, were taken by pressing into the soil a round tin about 6″ in height and 3″ in diameter in the furrow line where liquid ammonia was injected. The soil core thus collected was immersed in water and ammoniacal N was estimated in an aliquot of the water extract. The value for ammoniacal nitrogen thus obtained is considered as the ammonia in the soil pores present in a free state and which had not yet got into the exchange form. To follow the transformations of ammonia after injection, and at intervals afterwards, the soil samples collected

from the marked furrows were leached with normal NaCl solution and both the ammonia in the exchangeable form and the nitrate form in the extract estimated. The determinations of ammoniacal N were made by distillation with magnesium oxide directly and the total N after reduction of the nitrate N by Devarda's alloy. The following tables gives the contents of ammoniacal and nitrate N in the soils treated with liquid ammonia and with ammonium sulphate at similar nitrogen levels.

TABLE No. I

Analysis of water extract of soils

N. as p. p. m. of soil

Treatment	17-3-54 Ammoniacal N	24-3-54 Amm. N	1-4-54 Amm. N	14-4-54 Amm. N
1. Soil sample from plots treated with liquid ammonia Sample 1	38·0	20·8	1·3	0·0
2. Do. Sample 2	52·1	22·4	2·1	0·0
3. Soil sample from plots treated with Ammonium sulphate	4·0	0·5	0·0	0·0

TABLE No. II

Analysis of NaCl extract

N as p. p. m. of soil

	17-3-1954		24-3-54		1-4-54		1-4-54	
	Amm. N	Nitrate N	Amm. N	Nitrate N	Amm. N	Nitrate N	Amm. N	Nitrate N
1. Soil from liquid ammonia plot—Sample No. I.	56·0	11·2	49·3	12·4	24·7	20·9	11·2	71·7
2. Soil from liquid ammonia plot—sample No. II.	48·0	12·5	42·6	14·6	17·9	35·6	11·2	69·9
3. Soil from Am_2SO_4 plot	26·3	2·8	13·4	20·2	6·7	15·7	6·7	9·0

The loss of ammonia in the gaeous form occuring due to diffusion at soil surface after injection of liquid ammonia, was measured in another set of experiments by enclosing a known volume of standard hydrochloric acid contained in petri-dishes, inside a glass trough tightly placed over the soil surface in the furrows where ammonia was injected. The acid was left exposed to the atmosphere under the confined space of the trough for varying intervals and the acid neutralised by the evolving ammonia was determined by back titration against standard alkali. From the figures of ammonia escaping into the confined space of the inverted trough, the losses of the injected ammonia after varying lengths of time after injection were found out.

TABLE No. III

Loss of ammonia by diffusion from Soil surface after injection of liquid ammonia into the soil

	Intervals of time after which the acid was removed and titrated against alkali.	Volume of deci-normal HCl used up for neutralisation of NH_3 from an area of 1/16 sq yds in ccs	Mgs of NH_3 which escaped from an area of 1 sq. yard
1 set	10 minutes	1·3	39·4
	20 ,,	1·8	49·0
	30 ,,	0·9	24·5
	40 ,,	1·2	32·7
2 set	10 ,,	0·8	21·8
	20 ,,	1·9	51·7
	30 ,,	1·7	46·2
	40 ,,	1·4	38·1

The quantity of ammonia applied to the soil per square yard at the rate of 50 lbs of NH_3 per acre works out to 4690 mg per square yard.

DISCUSSION

The water extract (Table No. I) shows the presence of free ammoniacal N immediately after application of liquid ammcnia and the same practically disappears after about 2 weeks, indicating that some considerable time elapses before equilibrium is attained and ammonia gets fixed in the soil exchange complex. The NaCl extract (Table No. II.) reveals an initial high content of ammoniacal N in the ammonia treated plots and the same goes on diminishing week by week with a corresponding increase in the nitrate N whereas both the ammoniacal and nitrate N in the ammonium sulphate treated plot at corresponding periods are appreciably lower. This observation is supported by the findings of Eno, C. F. and Blue, W. G.[6] who find that nitrification of ammonia when applied to soil as such is more rapid than ammonium sulphate.

The quantity of ammonia lost due to diffusion at surface (Table No. III) is more or less constant irrespective of the period of exposure to the absorbing acid indicating that the amount of ammonia diffusing into the space confined in the glass trough reaches a maximum in the first few minutes after injection and thereafter remains steady. The quantity of ammonia lost due to escape from the surface seems to vary from 0·5 to 1·0% of the total ammonia injected into the soil, and as such the losses are not such as to cause any serious concern. Also the loss seems to occur only immediately after injunction when the gas issues at high pressure and the subsequent loss from diffusion is negligible. These findings are in keeping with the observations made in the U. S. A.[3] and other places where ammonia is being used for agricultural purposes.

SUMMARY

In this paper results of some preliminary chemical studies on the use of liquid ammonia as a fertilizer for crops is reported. The mechanism of injection of liquid ammonia into the soil, the transformation of injected ammonia in the

soil and the losses of ammonia occuring at the soil surface are discussed. It is found that ammonia is not immediately fixed into exchange complex but remains in a free state for one to two week after injection. The nitrification of ammonia in more rapid than ammonium sulphate. The losses of ammonia due to escape at the soil surface is found to be less than 1% of the quantity injected at depth into the soil.

REFERENCES

1. Gull, P. W. (1950). *Proc. Nat. Joint Comt. of Frt. appl.*, **26**, 72—77.
2. Higourdain, J. (1951). *Agriculture (Paris)*, **15**, 129.
3. Valentin, R. (1951). *Potasse*, **25**, 133—136.
4. Litynski, T., Jurkowaska, H. (1951). *C. R. M. Acad. polen. Sci. let.* No. 3—4, p. 2.
5. Brewe, C. A., Firman, H.A. (1953). *Proc. Soil Sci. Soc. Amer.*, **18**, 178—181.
7. Kurylowicz, B., Czekalski, A. (1953). *Roczn. Nauk. rol.* 67-*A*, No. 3, 5—22.

WATER REQUIREMENTS OF AGRICULTURAL CROPS

By

M. SANYASI RAJU

Agricultural Chemist (Retd.), Andhra State

and

F. L. DANIEL

Formerly Soil Physicist, Agricultural Research Institute, Coimbatore

Communicated by Prof. S. Ghosh

(*Recieved on 14th December, 1954*)

INTRODUCTION

Water is the most important limiting factor in crop growth. Nearly 75% of all plant life is composed of water. Plants grow luxuriantly in places where there is a plentiful supply of water. Rainfall is the natural source of supply of water for crop production. Wherever the rainfall is scanty man's ingenuity has been helpful in mitigating the trouble to a very great extent. This artificial method of supply water to plants is known as irrigation. This has taken different shapes in the hands of man. River projects, reservoirs, tanks, lakes, wells and artisan springs are some of them. Man's ingenuity consists in deverting water from where it is plentiful to where it is in short supply or in storing up water when it is plentiful to be used at time when it is most required by the plants.

The total area under irrigation in Madras State from the different sources of water supply are in the neighbourhood of 9,733,508 acres. Some of the most important crops that are grown under irrigation are paddy, sugarcane betel-vine and plantains. These require copious irrigation. In garden lands where lift irrigation is in vogue crops like cotton, millets, pulses, wheat, vegetables, fruits and flowers are raised.

Different types of irrigation are also adopted. Where the sources are tanks there flow irrigation is the rule and where wells and springs are the sources then lift irrigation is practised. So the water requirement of a crop will vary with the type of soil, with the kind of irrigation practised and also the crop. Different crops require different amounts of water for their growth and maturity depending upon their duration, their physiology and the naturally available rainfall. In other words with the same amonnt of water, different areas of different crops can be grown and the wisest course would be to utilise the water available for getting the largest area under cropping. This is the basic idea of what is known as the duty of water. The duty of water is defined as the area of a particular crop that can be succcssfully grown to maturity with a flow of one cusec of water during its growth including rainfall. The wet crops like paddy have a low duty of water in other words their water requirements are high. While the dry crops like millets and cotton have a high duty *i.e.*, their water requirements are low. Accurate figures for these duties are not available for these duties for all crops and all places. Some experiments have been conducted and the available figures for duty of water are presented.

Some of the 8 experiments on duty of water were conducted in connection with the lower Bhavani Project. The experiments were laid out in the *ryots* fields at Perundurai and Medachu in the Coimbatore Dt.Cotton, cumbu and ground nuts were the three crops tried. The supply source was wells. The water was led into a storing tank of known dimensions. It was felt that this technique could not be compared to conditions that would obtain under the project with flow irrigation. The experiments were continued during 1933—36 in Kugalur and Cheinnasamudram, where water was available by flow from channels. The results indicated that cotton and ground nuts required more water than could be met by the project while food and fodder crops would not be able to use up the available water. A judicious rotation of both food and commercial crops would be the most ideal. The experiments also showed that the duty of water for paddy was 30 and by remodelling the sluices this could be increased to 40.

Experiments conducted in *ryots* fields in Avadiaparai, Kugalur, Arkankottah and Tedapalli have shown that an allowance of 8 cusecs per square feet run of water is on the safe side.

In addition to these experiments, experiments on duty of water were started in 1938 in some of the Agricultural Research Stations.

Station	Crop	Nature of irrigation
1. Anakapalle	Sugar cane	Well
2. Maruteru	Paddy	Channel
3. Samalkota	Sugar cane	Channel
4. Nandyal	Cotton, sugarcane, paddy	Channel
5. Hagari	Combodia cotton	Well

Cotton Broding

Station	Crop	Source
CBE	Cotton	Well
Central Farm	Ragi and Cholam	Well
PBS CBE	Paddy	Tank
Palur	Paddy, sugarcane, Ground nuts	Well
Aduthurdi	Paddy	Channel
Kolipatti	Cambodia Cotton	Well

The results obtained are summarised below.

	Paddy	1st Crop (June to Dec.)	2nd Crop (Feb. to May)
Samba 57 (160 days)	Aduthurai (Kuruvai) (100 days)	68	Thaladi 80 (120 days)
—	Caimbatore	51	—
—	Maruteru	81	54
Samba 57	Pattukotai (Kuruvai)	37	Thaladi 67

It will be seen that the duty of water for paddy 1st crop varies from 37 in Pattukotai to 81 in Maruteru. In other words the water requirements in Pattukotai

is more than double that for the crop in Maruteru. It is, however, safe to assure that the duty of water is round about 50. The existing water resources can be better utilised if factors which contribute to losses like seepage and evaporation are controlled and by the evolution of varieties which are of shorter duration. The requirements of paddy at CBE all about 52—72".

Sugarcane.—The duty of water for sugarcane is 108 and for plantains it is 136. Other crops are Ragi which has a duration of 110 days and yields about 2000' per acre requires 18 to 24 including rainfall and the duty is roughly 130.

Cholam.—Cholam is raised from March to June and requires about 24" over a period of 100 days the duty is about 120.

Cotton.—The irrigated cotton is the Cambodia type. The duration of this crop is about 6 months. It requires nearly 28" of water, half of which could be had from rainfall. The duty for this crop is about 190.

It is not only the total quantity of water that is important but also the frequency of irrigation is a factor which is important. In Coimbatore experiments for cotton it is seen that 10 days interval is more suitable than 20 days interval. At Palur it was seen that irrigation at intervals of 3 days for paddy was beneficial. In Hagari experiments on cotton it was seen that a higher moisture level contributed to better growth and increase in number of internodes and an increase in the number of flowers and bolls. Shedding of bolls and flowers was also increase in the 3 varieties tried. At Coimbatore it was found that the 15th, 18th, and 21st weeks after sowing were found to be the critical periods for the cotton crop and 2 irrigations at 4 weeks intervals were found to be the most profitable from yield point of view and weekly irrigations were found to be unnecessary and wasteful.

The experiments conducted at Siruguppa show that the soil is permeable right up to the Garsu layer. The layer which is most affected by the irrigation or evaporation is the top 2" of soil. The maximum water content of the garsu layer is only ½ that of the soil layer. Different crops were tried at the Siruguppa station and the following table gives the comparative duty of water for these crops.

Mugari jonna	163
Hiugari jonna	265
Ragi	126
Wheat	234
Korra	103
Ground nuts	156
Paddy	60
Sugarcane	90

Thus it will be seen that the water requirements of the wet crops like paddy and sugarcane are very high while the dry crops have a low water requirements, roughly it is about ½ to ⅓ of that for paddy.

NITRIFICATION STUDIES ON MANURIAL POSSIBILITIES OF MAIZE OIL-CAKE

By

N. K. DAS *and* N. S. SINHA

Main Sugarcane Research Station, Shahjahanpur

Communicated by Prof. S. Ghosh

(*Received on 18th December, 1954*)

The maize oil-cake is bye-product of starch manufacture, which is available in large quantities in some factory areas of the State. It contains 3·6 % nitrogen, and C/N ratio more than 14. It is comparable to *mahu va* cake in its nitrogen content. It was previously burnt but recently some attempts have been made to utilize it as a manure. As results obtained in field trials were not uniformly encouraging it was decided to carry out laboratory nitrification studies with three typical soils of the *tarai* areas. The results obtained in these studies have been given in the present publication.

Saharsbudhe and Ghatikar (1931) carried out nitrification studies with soils of Bombay Deccan and showed that the addition of lime to medium black soils increases nitrification. Basu (1949) studied nitrification of sulphate of ammonia and farmyard manure in five soil types commonly obtained in the canal irrigated areas of Bombay State and found that the inherent nature of soils determined the course of nitrification. In laboratory expriments with five soils to which hoof and horn, and dried blood materials were added at different concentrations, Owen and Windsor (1950) have shown that the percentages organic nitrogen nitrified throughout the transformation were largely dependent on levels of application of the manures. Mukerji, Pramanik and Misra (1947) adopted the microbiological decomposition methods for assessing fertility status of some sugarcane soils. Bennet and Allison (1928), Waksman (1931) and Brown (1936) indicated the importance of soil in the nitrification of ammonium sulphate and organic manures.

In the present studies the technique developed by Winogradsky (1893) has been adopted for studying the course of nitrification in different soil types.

DATA AND DISCUSSIONS

Two experiments were carried out to study the nitrification of the manures in the soils of the Matkhera series. In the first experiment, the manures used were sulphate of ammonia and maize oil-cake at 30 mgms of nitrogen per 100 gms of soil of each textural soil type, namely sandy loam, loam and clay. Some typical analytical data of the soils are given in Table No. I.

TABLE No. 1

Chemical and Physio-chemical determinations of soils of Matkhera series, Rampur

	Sandy loam	Loam	Heavy loam
Total bases m.e.%	15·00	18·50	26·25
Ex-Ca, m. e.%	4 00	14·50	22·75
Total nitrogen	0·064%	0·083%	0·141%
Organic carbon	--	0·901%	0·946%
Water holding capacity	34·43%	46·66%	48·77%
Moisture equivalent	19·46	31·3%	35·4%
pH.	7·2	7·5%	7·6%

The soils were incubated at the room temperature in the dark and moisture maintained throughout the period of eight week at one third of the water holding capacity. The samples were kept in duplicate, in pyrex bottles plugged with cotton wool. At the end of each week an aliquot was removed from each bottle and, ammonical and nitrate nitrogen determined in KCl. extract by Olsen's method as modified by Richardson (1938). The results obtained are given in Table No. II.

The nitrate content in sandy loam soils as the end of the first week was high and it progressively decreased thereafter, and at the end of eight weeks there was very little of ammonical and nitrate nitrogen left. With the application of sulphate of ammonia, maximum nitrification was obtained in the 4th week when approximately 64% of added nitrogen could be found in the soil extract in the form of nitrate and ammonia. The rest of nitrogen could not be found in the leachate. It is presumed that in view of the prevailing acidic conditions, the residual part of the added nitrogen was used up in the metabolic tissue formations by the soil micro-organisms. It is also possible that some of added nitrogen may have been lost through denitrification. With maize oil-cake, however, maximum nitrification was obtained in the 8th week when about 70 % of maize oil-cake nitrogen was fully nitrified.

In loam soils the amount available nitrogen in the beginning was fairly high in the control bottles and gradual loss of available nitrogen took place during the incubation period but at a slower rate and to a lesser extent than in sandy loam soil. With the addition of sulphate of ammonia, maximum nitrification was observed in the 8th week when about 6·6% of added nitrogen was fully nitrified. With maize oil-cake however, the rate of nitrification was slower and at the end of 8th week only about 52% of the nitrogen was nitrified.

In clay loam soils the amount of the available nitrogen in the control bottles was low at the beginning, and at the end of 8 weeks the available nitrogen (ammonical and nitrate nitrogen) was approximately 40% more than that at the beginning. With the addition of sulphate of ammonia, the nitrate nitrogen content increased almost immediately and at the end of 8 weeks, 70 % of the added nitrogen was very slow and only about 15% of the added nitrogen was nitrified.

The data given in Table No. II indicate, therefore, that maize oil-cake nitrifies as well as sulphate of ammonia in sandy loam soil but in loam and in clay loam soils it does not nitrify satisfactorily. It is also indicated that sulphate of ammonia nitrifies almost to the same extent in all the three types of soils.

TABLE No. 11

Nitrification of sulphate of ammonia and maize oil-cake in soils of Matkhera series, Rampur, U. P.

(Mg of NH_3 and NO_3 nitrogen in 100 gm soil)

Type of soil	Treatments	1st week NH_3	1st week NO_3	2nd week NH_3	2nd week NO_3	3rd week NH_3	3rd week NO_3	4th week NH_3	4th week NO_3	6th week NH_3	6th week NO_3	8th week NH_3	8th week NO_3
I. Rampur sandy Loam soil Matkhera	1. Control	5·6	8·1	1·8	6·2	2·4	4·9	1·8	6·84	·18	5·6	·62	·81
	2. Ammonium sulphate at 30 mg per 100 gm soil	16·2	13·0	15·5	11·8	6·2	16·8	4·9	23·3	1·87	22·4	1·87	21·74
Farm block No. 4 plot No. 32	3. Maize oil-cake at 30 mg per 100 gm soil	11·8	8·0	5·6	15·5	3·1	16·1	3·1	19·9	1·24	21·1	·62	21·9
II. Rampur loam soil Matkhera farm Block No. 1 plot No. 23	1. Control	9·1	9·1	4·5	5·8	1·9	8·4	1·95	8·4	·65	9·1	·65	7·81
	2. Ammonium sulphate at 30 mg per 100 gm soil	10·4	22·0	5·2	18·9	3·2	25·0	1·30	30·0	1·30	26·04	·65	31·2
	3. Maize oil-cake at 30 mg per 100 gm soil	9·7	3·9	3·2	6·5	3·9	14·3	2·60	15·6	1·95	14·90	·65	23·4
III. Rampur heavy loam Matkhera farm block Block No. III plot No. 6	1. Control	4·6	4·6	1·3	5·2	3·2	9·8	3·29	11·2	·65	9·89	·33	12·5
	2. Ammonium sulphate at 30 mg per 100 gm soil	7·2	21·0	1·3	4·6	2·6	26·3	1·30	27·0	1·31	27·0	8·13	33·6
	3. Maize oil-cake at 30 mg per 100 gm soil	5·9	4·6	3·3	3·2	3·2	8·5	3·29	12·5	1·31	14·50	·66	13·9

In view of the above results a second series of nitrification studies were carried out with sulphate of ammonia and maize oil-cake alone and in combinations, with three doses of application, namely, 0, 10 and 20 mgs of nitrogen per 100 gms of soil and also with 30 mgs of nitrogen of either of the manures. Both loam and clay loam soils were used and moisture maintained at 40% of water holding capacity. The soils were incubated in dark in duplicate and aliquot removed at the end of every week for analysis. The results obtained are given in Table No. III. The details of the individual treatments are givrn below :—

1.	Control.						
2.	No maize oil-cake, 10 mgs N in the form of sulphate of ammonia.						
3.	No maize oil-cake, 20 mgs N in the form of sulphate of ammonia.						
4.	10 mgs N in the form of maize oil-cake. No sulphate of ammonia.						
5.	10 mgs N in the form of maize oil-cake	; 10 mgs N	,,	,,			
6.	10 ,,	,,	,,	; 20	,,	,,	,,
7.	20 ,,	,,	,,	; No	,,	,,	,,
8.	20 ,,	,,	,,	; 10	,,	,,	,,
9.	20 ,,	,,	,,	; 20	,,	,,	,,
10.	30 ,,	,,	,,	; No	,,	,,	,,
11.	No ,,	,,	,,	; 30	,	,,	,

In loam soils the maximum nitrification of 17·5 mgs nitrogen was obtained in treatment 6, namely, with a mixture consisting of 10 mgs of nitrogen of maize oil-cake and 20 mgs of sulphate of ammonia. This respresents an over all nitrification of 59% of the added nitrogen. Since the total nitrates formed arise out of nitrification of sulphate of ammonia nitrogen up to 46% and maize cake nitrogen up to 54%, it is clear that in the overall nitrification the effects of the components of the mixture are additive. In this soil type a dose of 20 mgs of nitrogen from either source gave better nitrification than the doses, 10 or 30 mgs N per 100 gms of soil but the mixture consisting of 20 mgs of nitrogen of both the manures gave a lower value. It appears that there is an interaction between the manures and soil when the doses of oil-cake nitiogen is increased in mixtures from 10 mgs to 20 mg.

In heavy loam soils the best nitrification with 10 mgs of nitrogen of sulphate of ammonia was obtained in the 4th week with 20 mgs of nitrogen in the 6th week and with 30 mgs in the 8th week. The maximum nitrification was obtained with 20 mgs of nitrogen per 100 gms of soil. With oil-cake the best nitrification was also obtained with 20 mgs of nitrogen in the 4th week but with 30 mgs of nitrogen in the 4th week but with 30 mgs of nitrogen the results were very low. With the four mixtures of sulphate of ammonia and oil-cake namely 10:10, 20:10, 20:20 and 10:20 respectively the best nitrification was obtained with 20:20 and 10:20 mixtures of sulphate of ammonia and oil-cake. In the former case the effects of components of the mixture appear to be additive, while in the latter case there appears to be some interaction.

GENERAL DISCUSSION

The data given in the foregoing pages indicate that sandy loam soils of Matkhera series are quite suitable for the proper nitrification of sulphate of ammonia and maize oil-cake. The satisfactory nitrification is due, in this case possibly, to proper soil aeration. In sandy loam soils maize oil-cake nitrifield to the extent of 70% and in loam soils, 52% while clay loam up to 15% only. In loam and clay soils the low nitrification of maize oil-cake could be ascribed to the lack of proper soil aeration. In the case of sulphate of

TABLE No. III

Nitrification of sulphate of ammonia and maize oil-cake separately and in combination in loam and heavy loam soils of Matkhera series. (Mg of NH_3 and NO_3 nitrogen in 100 mg soil)

Treatments	Type of soil	2nd week NH_3	2nd week NO_3	4th week NH_3	4th week NO_3	6th week NH_3	6th week NO_3	8th week NH_3	8th week NO_3
1. Control	Loam	·46	2·3	·92	2·76	·46	2·3	·46	2·76
2. Sulphate of ammonia at 10 mg per 100 gm soil	,,	1·84	4·6	·46	5·52	2·30	6·9	2·30	1·84
3. Sulphate of ammonia at 20 mg per 100 gm soil	,,	5·52	...	·46	8·28	2·88	11·96	7·36	2·76
4. Maize oil-cake at 10 mg per 100 gm soil	,,	·92	...	5·02	0·92	3·22	5·02	2·76	1·84
5. Maize oil-cake at 10 mg. and sulphate of ammonia at 10 mg per 100 gm soil	,,	·92	7·36	2·76	4·60	1·38	10·12	3·68	2·76
6. Maize oil-cake at 10 mg and sulphate of ammonia at 20 mg per 100 gm soil	,,	3·22	12·42	1·38	16·56	1·38	17·48	5·98	2·76
7. Maize oil-cake at 20 mg per 100 gm soil	,,	...	9·20	4·60	10·12	1·38	13·34	8·28	2·30
8. Maize oil-cake at 20 mg and sulphate of ammonia at 10 mg. per 100 gm soil	,,	3·68	11·04	5·52	16·56	1·84	12·42	5·98	2·30
9. Maize oil-cake at 20 mg and sulphate of ammonia at 20 mg per 100 gm soil	,,	5·98	3·16	3·68	10·12	4·60	14·72	6·90	3·68
10. Maize oil-cake at 30 mg per 100 gm soil	,,	3·22	...	5·52	1·38	9·66	6·44	9·66	1·84
11. Sulphate of ammonia at 30 gm per 100 gm soil	,,	9·66	8·74	12·42	7·36	6·44	13·80	...	5·52

1. Control.	Heavy loam	1·40	2·8	1·4	2·9	0·7	2·8	...	2·8
2. Sulphate of ammonia at 10 mg per 100 gm soil.	,,	2·8	4·2	4·2	7·0	...	3·5	2·8	4·9
3. Sulphate of ammonia at 20 mg per 100 gm soil.	,,	2·8	4·0	5·6	9·1	1·4	16·8	5·6	7·7
4. Maize oil-cake at 10 mg per 100 gm soil.	,,	2·1	2·1	2·8	3·5	...	3·5	1·4	3·5
5. Maize oil-cake at 10 mg and sulphate of ammonia at 10 mg per 100 gm soil.	,,	0·7	4·9	1·4	7·0	6·3	3·5	2·8	5·6
6. Maize oil-cake at 10 mg and sulphate of ammonia at 20 mg per 100 gm soil.	,,	...	11·2	1·4	9·8	5·6	4·9	...	11·4
7. Maize oil-cake at 20 mg per 100 gm soil.	,,	10·5	10·5	2·1	16·1	7·7	3·5	1·4	8·5
8. Maize oil-cake at 20 mg and sulphate of ammonia at 10 mg per 100 gm soil.	,,	5·6	6·3	1·4	18·2	...	12·6	2·1	14·7
9. Maize oil-cake at 20 mg and sulphate of ammonia at 20 mg per 100 gm soil.	,,	5·6	6·3	2·1	18·2	6·3	10·5	0·7	10·6
10. Maize oil-cake at 30 mg per 100 gm soil.	,,	2·1	4·9	2·1	7·0	9·8	6·3	3·5	5·6
11. Sulphate of ammonia at 30 mg per 100 gm soil.	,,	4·2	7·7	1·4	11·2	1·4	10·6	...	15·4

ammonia in all the three types of soil approximately 30% of the added nitrogen could not be extracted, in the cases when the level of application was at the rate of 30 mg N per 100 gms of soil. It is presumed that about a third of the added nitrogen of sulphate of ammonia and also that due to ammonification of maize oil-cake, may have been locked up in the excessive microbial tissue formation in this soil type.

In heavy loam soils a 2:2 mixture of sulphate of ammonia and maize oil-cake nitrogen was found to be better than 1:1 mixture. In loam soils the best nitrification was obtained with a mixture of 2:1 sulphate of ammonia and maize oil-cake nitrogen representing a nitrification of 46% sulphate of ammonia nitrogen and approximately 54% that of oil-cake a 1:2 mixture is also equally effective but in this case there is considerable delay in nitrification. In clay loam soils are best the results were obtained only in the 8th week and 2:1 and 2:2 mixtures of sulphate of ammonia and maize oil-cake were found to be better than maize oil-cake alone. It is clear from this experiment that high C/N ratio of maize oil-cake may partly be responsible for its indifferent nitrification in loam and clay loam soils.

SUMMARY

Nitrification studies were carried out with sulphate of ammonia and maize oil-cake in *tarai* soils found next to the foot hills of the Himalayas in U. P. It was found out that maize cake nitrified as well as sulphate of ammonia in sandy loam soils only. In loam and heavy loam soils the nitrification of the oil-cake was not satisfactory.

It was found that more satisfactory nitrification in these soils was possible only when oil-cake is mixed with sulphate of ammonia in different proportions.

ACKNOWLEDGMENTS

The investigations forming the subject-matter of the article were carried out at the Main Sugarance Research Station, Shahjahanpur, financed jointly by the Indian Central Sugarance Committee and State Government. The financial help of the Committee is gratefully acknowledged. Thanks of the authors are due to Dr. B. K. Mukerji, Additional Director of Agriculture, U. P., for his kind and valuable suggestions throughout the course of the investigations. The authors would like to express their indebteness to Dr. R. K. Tandon, Director Sugarcane Research, for kindly reading through the manuscript and helping the authors in its preparation.

REFERENCES

1. Basu, J. K. (1944). Studies in availability of Nitrogen in Farmyard manure and sulphate of ammonia when applied to various soil types. *Ind. Jour. Agri. Sci., XIV.*

2. Bennet, H. H. and Allison R. V. (1928). The soils of Cuba, Tropical Plant Res. Foundation, Washington, D. C.

3. Brown, P. E. (1936). Soils of Iowa Sp. Report No. 3. *Soils Sub-section-Agronomy-Section, Iowa Agric. Expt. Sta.*

4. Mukerji, B. K., Pramanik, B. N. and Misra, A. N. (1949). Sugar Factory Pressmud, oil-cakes and sulphate of ammonia in the soil and the relative population of Azotobacter chrooccum in each treatment. *19th Proc.* Part II *of Sugar Tech. Assoc. of India.*

5. Owen, O., Rogers, D. W. and Windsor, G. W. (1950). The nitrification of some nitrogenous Fertilizers, *Jour. Agric. Sci.*, 40, Parts 1 and 2.
6. Olsen, C. (1929). Compt. Rend. Trav. Lab. Carlsberg, Seen from Piper C. S. Soil and Plant Analysis, 1948., Vol. 17, pp. 1—20.
7. Richardson, H. L. (1938), *Jour. Agric. Sci.*, 28, 73—121.
8. Saharsbudhe, D. L. and Ghatikar, B. H. (1931), Nitrogen recuperation in the soils of the Bombay Presidency, Part II, *Ind. Jour. Agric. Sci.*, *I.*
9. Waksman, S. A. (1931). Principles of soil Microbiology. Williams and Wilkins, Co. Baltimore, U. S. A.

GREATER BENEFICIAL EFFECTS OF SUPER-PHOSPHATES WITH 1 MOL OR 1/2 MOL OF H_2SO_4 THAN WITH 2 MOLS OF H_2SO_4

By

N. R. DHAR and B. K. DHAR

Sheila Dhar Institute of Soil Science, University Allahabad

(Received on 20th December, 1954)

In has been observed that the addition of phosphates as a fertilizer is a wasteful process, because the recovery of phosphate in the crop production is small and is normally not more than 20—30% in temperate country soils which have a tendency to be acidic.[1] In the neutral and alkaline soils of warm countries the monocalcium salt cannot remain very long in the soil as such but readily reverts to $Ca_3(PO_4)_2$ and $CaHPO_4$ and thus the available P_2O_5 decrases markedly. W. H. Fuller and W. T. McGeorge[2] have observed that in Arizona soils calcium is considered to unite with soluble phosphorus to form phosphates of varying degrees of solubility.

P. Parish (Calcium, super-phosphate and complex fertilisers, their chemistry and manufacture, pp. 12—24). has observed : "The quantity of phosphoric acid obsorbed by a plant from the super-phosphate during the first year seldom exceeds 40% of the total used, and may even be as low as 15—25%. In acid soils it is even lower than the latter figure. Clearly a modern fertilizer should be more efficient than this. That the super-phosphate industry by which to reduce or otherwise avoid the fixation of phosphoric acid seems obvious."

In view of the above facts the authors prepared super-phosphates from Indian phosphate rocks with 2 mols of sulphuric acid, 1 mol of sulphuric acid and 1/2 mol of sulphuric and finally they were applied to the different types of Indian soils.

PREPARATION OF SUPER-PHOSPHATES

Super-phosphates were prepared by the action of sulphuric acid on bone or phosphate rock and the following reactions which are involved in the manufacture of super-phosphate on the Industrial scale[3] :—

$$3\,Ca_3(PO_4)_2 + 6H_2SO_4 + 11\,H_2O = 4H_3PO_4 + Ca_3(PO_4)_2 + 6\,CaSO_4\,2\,H_2O$$

and

$$4H_3PO_4 + Ca_3(PO_4)_2 = 3\,CaH_4(PO_4)_2\,H_2O$$

Simply the reaction is expressed as follows :—

$$Ca_3(PO_4)_2 + 2H_2SO_4 + 5H_2O = CaH_4(PO_4)_2\,H_2O + CaSO_4\,2H_2O$$

According to the above reactions 310 parts by weight of ground tricalcium phosphate are mixed with 190 parts of sulphuric acid and 90 parts of water. The

resulting jelly is left to dry, and the mass is beaten up with water, the filtrate will contain monocalcium phosphate.

We have prepared three varieties of super-phosphates by adding 196, 98, 49 parts sulphuric acid to 310 parts of ground rock phosphate respectively.

The water soluble and citric acid soluble amounts of these super-phosphates are as follows :—

Behar Super-phosphate

Phosphorus soluble in	Super-phosphate with 1/2 mol H_2SO_4	Super-phosphate with 1 mol H_2SO_4	Super-phosphate with 2 mols H_2SO_4
	Percentage of P_2O_5 in terms of total P_2O_5		
Water	3·6	14·6	50·8
1% citric acid	11·4	22·2	35·5
	Trichinopoly super-phosphate Sample No. II		
Water	4·7	17·4	57·0
1% citric acid	12·6	23·2	61·2
	Trichinopoly super-phosphate Sample No. I		
Water	80·7	4·2	...
1% citric acid	17·0	10·9	...

With the Trichinopoly phosphate rock No. I the super-phosphate with 2 mols of H_2SO_4 could not be obtained readily as it remained wet for a long time.

EXPERIMENTAL PROCEDURE

0·25% P_2O_5 in the form of the above prepared super-phosphates were added to the two varieties of Indian soils. After definite intervals of time the soil samples were taken for the analysis of available phosphate (1% citric acid soluble P_2O_5). The available phosphate was determined by the method described by Dyer[4] and the further procedure was carried out according to the method described by Pemberton.[5]

Cane sugar molasses and wheat straw were used as source of decomposing organic matter.

Experimental results with normal soil and Cane sugar molasses

(Concentration of P_2O_5 0·25%)

Treatment	Available phosphate in grms per 100 grms of soil: After 0 days	After 50 days	After 100 days
Soil+1% molasses	0·0329	0·0331	0·0334
,, + ,, + Super-phosphate with 2 mol H_2SO_4	0·2432	0·1592	0·1564
,, + ,, + Super-phosphate with 1 mol H_2SO_4	0·2001	0·1623	0·1620
,, + ,, + Super-phosphate with 1/2 mol H_2SO_4	0·0877	0·1321	0·1348

Experimental results with good soil and Wheat straw

(Concentration of P_2O_5 0·25%)

Treatment	Available phosphate in grms per 100 grms of soil After 0 days	After 90 days	After 180 days
Soil + 1% straw	0·1708	0·1709	0·1711
,, + ,, + Super-phosphate with 2 mols H_2SO_4	0·3960	0·2742	0·2242
,, + ,, + Super-phosphate with 1 mol H_2SO_4	0·3250	0·2265	0·2171
,, + ,, + Super-phosphate with 1/2 mol H_2SO_4	0·2464	0·2521	0·2600

Experiments with normal soil and Ammonium sulphate
(Concentration of P_2O_5 0·10%)

Treatment	Available phosphate in grms per 100 grms of soil After 0 days	After 40 days	After 80 days
Soil+ammonium sulphate	0·0285	0·0285	0·0285
,, + ,, + Super-phosphate with 2 mols H_2SO_4	0·0943	0·0634	0·0532
,, + ,, + Super-phosphate with 1 mol H_2SO_4	0·0732	0·0647	0·0620
,, + ,, + Super-phosphate with 1/2 mol H_2SO_4	0·0345	0·0421	0·0457

From the above results it is clear that the super-phosphates prepared by adding 1/2 mol H_2SO_4 on phosphate rock, has got less available phosphate in the beginning than that present in the system to which super-phosphate prepared with 2 mols of sulphuric acid or 1 mols of sulphuric acid. On the other hand the super-phosphates with 2 mols or 1 mol of sulphuric acid have got a high available P_2O_5 in the beginning, but it goes on decreasing with lapse of time, while in the former case it goes on inceasing with the lapse of time.

As has already been stated that when 2 mols of sulphuric acid are added to a definite weight of powdered phosphate rock, the super-phosphate formed as is done in the industrial preparation of super-phosphate, is much more soluble than the super-phosphate prepared by adding 1 mol of sulphuric acid. Our experiments show that the available phosphate in the super-phosphate prepared with 1 mol of sulphuric acid when compared with available phosphate present in the super-phosphate prepared with 2 mols of sulphuric acid is not widely different. As a matter of fact the available phosphate in the super-phosphate prepared with 2 mols of sulphuric acid falls off much more readily with lapse of time due to the reversion of soluble calcium monophosphate to the dicalcium phosphate and tricalcium phosphate than with super-phosphate with 1 mol of sulphuric acid.

Moreover, in the case of super-phosphate prepared with 1/2 mol of sulphuric acid the available phosphate is about 1/2 that prepared with 2 mols of sulphuric

acid, but unlike the super-phosphates prepared with 2 mols of sulphuric acid or 1 mol of sulphuric acid the availability of super-phosphate with 1/2 mol of sulphuric acid increases appreciably with time. This is a very important point in fàvour of the view that the super-phosphate containing smaller doses of sulphuric acid, which is short these days in the world, should prove to be of immense value to the farmers in the poor countries. It is well-known that the "*kotka*" super-phosphate prepared and used in Finland and "Semol" super-phosphate used in Ireland in which almost ½ the quantity of sulphuric acid has been used than is required in the industrial production of ordinary super-phosphate have proved highly beneficial in these countries of which the soil has the tendency to be acidic.

From the above it appears that the production of super-phosphate with smaller doses of sulphuric acid should be encouraged for the better crop production in permanent agriculture with less cost.

SUMMARY

1. The super-phosphates prepared with 2 mols or 1 mol of sulphuric acid when added to the soil has got high P_2O_5 in the beginning but it goes on decreasing with lapse of time, due to the conversion of monocalcium phosphate into dicalcium phosphate.

2. The super-phosphates prepared with 1/2 mol of sulphuric acid has got less available P_2O_5 in the beginning but it goes on increasing in due course of time.

3. "*Kotka*" super-phosphate used in Finland and "Semol" super-phosphate used in Ireland in which almost 1/2 quantity of sulphuric acid has been used than is required industrially, have proved highly beneficial in these countries.

4. Preparation of super-phosphates with smaller doses of sulphuric acid should be encouraged for permanent agriculture.

REFERENCES

1. Dhar, N. R., (1954). *Kungl. Lant. Aualer.*, **21**, 50--80.
2. Fnller, W. H. and McGeorge, W. T. (1950). *Soil Sci., Vol.* 70.
3. Rogers and Allen (1951). "*Industrial Che*..."
4. Dyer, B., (1894). *Trans. Chem. Soc.*, 65, 1
5. Pemberton, (1930). *Methods of Analysis, A*

d Cane su
$)_5$ 0·25%
le phosp
per 10
s Aft

VALUE OF INDIAN PHOSPHATE ROCKS IN SOIL FERTILITY AND CROP PRODUCTION

By

N. R. DHAR *and* B K DHAR

Sheila Dhar Institute of Soil Science, University of Allahabad

(Received on 20th December, 1954)

Dhar and co-workers[1] have carried on for over 25 years a large amount of research work on the problem of nitrogen fixation and the influence of calcium phosphate on this phenomenon and of soil fertility.

Phosphate rock is the cheap form of calcium phosphate. It has been observed by Lang[2] that raw rock phosphates build up long lasting soil fertility, while super-phosphates give fast nourishment to current crops. One of the first advocates of raw rock phosphate was Hopkins of the University of Illinois. His influence in this matter was so great that today Illinois uses 600,000 tons of phosphate rock each year and Missouri uses 200,000 tons each year.

Dhar[3] has recently advocated that organic substances undergo oxidation in the soil forming carbonic acid. Moreover, there is formation of nitrous acid (Dissociation constant$=6\times10^{-4}$) and nitric acid in soils when nitrogenous compounds undergo ammonification and nitrification in the soil. When carbonic acid is passed into water containing tricalcium phosphate in suspension, the formation of dicalcium phosphate has been reported. Hence, phosphate rocks, especially soft rocks not containing calcium fluoride and other sparingly soluble phosphates are made available to crop when they are mixed with farmyard manure, straw, green manures etc., which are oxidized slowly in the soil. The neutral phosphates when mixed with organic matter the following reaction are though to take place.

$$Ca_2\ (PO_4)_2 + 2\ H_2\ CO_3 = 2\ Ca\ HPO_4 + Ca(HCO_3)_2$$

$$Ca_3\ (PO_4)_2 + 4HNO_3 = 2Ca(NO_3)_2 + Ca(H_2PO_4)_2$$

From the analysis of Indian phosphate rocks it seems that they are not suitable for the manufacture of super-phosphates.

Analysis of Rock phosphates collected from different parts of India

Origin of the Phosphates rock	Constituents %							
	SiO_2	Fe_2O_3	Al_2O_3	P_2O_5	CaO	MgO	Cl	SO_3
1. Phosphate rock from Trichnopoly No I	30·45	24·31	12·63	19·86	11·62	0·60	0·031	1·00
2. Phosphate rock from Behar	5·52	3·92	22·12	27·9	11·8	0·30	0·70	0·03
3. Phosphate rocks from Trichnopoly No. II	6·30	4·20	26·5	27·5	20·8	1·75	0·89	0·05

While the analysis of representative samples of rock phosphates used for the manufacture of super-phosphates is[10] :—

Consituent	Wyoming %	Utah %	Idaho %	Montana %
Insoluble	10·00	9·40	2·62	6·00
SiO_2	...	...	0·46	...
Al_2O_3	0·89	0·90	0·97	1·10
Fe_2O_3	0·73	0·33	0·40	0·450
MgO	0·28	0·26	0·35	0·30
CaO	45·34	46·80	48·91	46·90
Na_2O	1·10	2·08	0·97	...
K_2O	0·48	0·58	0·54	...
P_2O_5	27·37	32·05	33·61	32·10
F	0·60	0·66	0·40	...

For the useful utilization of the rock phosphates found in India, the authors have added these powdered (finely) phosphates rocks to the soils in presence of certain organic matters like molasses, wheat straw, etc.

Nitrogen fixation by a mixture of organic matter like cane sugar molasses and wheat straw in presence of phosphate rocks.—The authors have carried out experiments on the influence of phosphate rocks on the fixation of atmospheric nitrogen. 0·25% P_2O_5 in the form of above mentioned phosphate rocks of Indian origin were added to the two varities of Indian soils. The moisture content of all the experiments was maintained at 20%. After definite intervals of time the soil samples were taken for the analysis of carbon, total nitrogen, available phosphate and exchangeable calcium. The total carbon was determined by the method described by Robinson, Mclean and Williams,[4] total nitrogen was estimated by salicylic acid reduction method[5], available phosphate was determine by Dyer[6] method and further procedure was carried out according to the method described by Pemberton.[7] The exchangeable calcium was determined by ammonium acetate leaching method and the further procedure was followed as mentioned by Piper.[8]

Experimental results with cane sugar molasses and phosphate rock.—The average temperature of the system in these experiments exposed to electric bulb light or kept in the dark is 30°C.

Percentage composition of oven-dried soil

Period of exposure in days	Carbon oxidized	Nitrogen fixed	Efficiency *i.e.*, nitrogen formed in milligrams per gram of carbon oxidized	Available P_2O_5	Exchangeable calcium in m.e.
		200 grms of soil+2 grams molasses			
			Light		
0	...	...	...	0·0329	22·9
50	0·2772	0·01225	44·2	0·0331	24·2
100	0·2986	0·01433	48·0	0·0334	24·8
			Dark		
0	...	...	...	...	...
50	0·2691	0·0064	23·8	...	...
100	0·2740	0·0069	25·0	...	...

Period of exposure in in days	Carbon oxidized	Nitrogen fixed	Efficiency *i.e.*, nitrogen formed in milligrams per gram of carbon oxidized	Available P_2O_5	Exchange-able calcium m.e.
200 gms of soil+2 grms molasses+0·25% P_2O_5 as Phosphate rock of Trichinopoly No. 1 (India)					
Light					
0	...	...	...	0·0356	23·4
50	0·2869	0·01457	50·8	0·0398	28·6
100	0·3081	0·01691	54·9	0·0448	30·7
Dark					
0	...	...	...	...	...
50	0·2710	0·00742	26·9	...	...
100	0·2831	0·00886	31·3	...	...
200 grms of soil+2 grms molasses+0·25% P_2O_5 as Phosphate rock of Behar					
Light					
0	...	...	...	0·0382	23·0
50	0·2871	0·01469	51·2	0·0442	27·9
100	0·3080	0·01706	55·4	0·0471	31·4
Dark					
0	...	...	...	...	...
50	0·2724	0·00702	27·4	...	...
100	0·2834	0·00841	29·7	...	...
200 grms of soil+2 grms molasses+0·25% P_2O_5 as Phosphate rock of Trichnopoly No. II					
Light					
0	...	...	...	0·0384	2·31
50	0·2866	0·01444	50·4	0·0420	27·8
100	0·3082	0·01661	53·2	0·0469	30·5
Dark					
0	...	...	...	...	...
50	0·2712	0·00718	26·5	...	...
100	0·2835	0·00819	28·9	...	...
200 grms of soil+2 grms molasses+0·25% P_2O_5 as Phosphate rock of Kudada					
Light					
0	...	...	...	0·0395	24·0
50	0·2863	0·01465	51·2	0·0496	29·4
100	0·3084	0·01690	54·8	0·0598	31·5
Dark					
0	...	...	...	...	...
50	0·2710	0·00740	27·4	...	...
100	0·2830	0·00800	28·6	...	...

Experiments with good soil, wheat straw aad Phosphate rocks

Period of exposure in days	Carbon oxidized	Nitrogen fixed	Efficiency *i.e.*, nitrogen formed in milligram per gram of carbon oxidized	Available P_2O_5	Exchangeable calcium in m. e.
		200 grms soil + 2 grms Wheat straw			
		Light			
0	...	...	...	0·1708	39·5
90	0·3954	0·05330	135·0	0·1709	39·7
180	0 5001	0·06511	130·2	0·1711	39·6
		Dark			
0	...	...	...	...	...
90	0·2978	0·02320	70·1	...	...
180	0·4087	0·02990	73·4	...	...
		200 grms of soil+2 grms wheat straw+0·25% P_2O_5 as Phosphate rock of Behar			
		Light			
0	...	...	...	0·1906	40·2
90	0·4164	0·0617	148·3	0·1925	43·1
180	0·5115	0·0737	144·3	0·1936	44·5
		Dark			
0	...	...	...	...	...
90	0·3670	0·0311	85·0	...	...
180	0·4481	0·0385	86·0	...	...
		200 grms of soil+2 grms wheat straw+0·25% P_2O_5 as Phosphate rock of Trichinopoly I			
		Light			
0	...	...	...	0·1896	40·0
90	0·4170	0·0626	150·3	0·1989	43·8
180	0·5127	0·0758	148·2	0·2001	44·7
		Dark			
0	...	...	...	...	...
90	0·3670	0·0287	75·0	...	...
180	0·4417	0·0338	76·6	...	...

From the foregoing results it is clear that there is almost in every experiment an appreciable increase in the nitrogen content. The addition of phosphate rocks enhance the nitrogen fixation and thus gives a higher efficiency (nitrogen fixed in mg per gm of carbon oxidized). It is also seen from the experimental results that when either molasses or wheat straw is allowed to undergo oxidation

in air in contact with soil there is always a decrease in the carbon content and a concomitant increase in the nitrogen content of the system. This effect is more pronounced in light than in the dark.

Dhar[9] in many of his publications has attributed the increase of nitrogen to the fact that the organic matter when added to the soil undergoes oxidation resulting in the liberation of energy. This energy in its turn is used in fixing the atmospheric nitrogen when light acts on the system, whether from the sun or artificial source, a part of it is absorbed and causes a greater fixation of nitrogen.

It has also been observed from the experimental results that the availability of phosphates appreciably increases in presence of organic matter, specially in the case of molasses which undergoes decomposition and oxidation in the soil. The carbonic acid and small amounts of other weak organic acids produced from molasses are helpful in the conversion of tricalcium phosphate into the dicalcium phosphate and small amounts of monocalcium phosphate which are more soluble in water than tricalcium phosphate. There is also an appreciable increase in exchangeable calcium when phosphate rocks are added to the system due to the formation of dicalcium and monocalcium phosphates from tricalcium phosphate. From the experimental results it is clear that in Allahabad where the average temperature of the soil in the year is 26°C and the soils have a tendency to be on the alkaline side, the available phosphate even when powdered rock phosphate is added increases appreciably and it reaches the values 866·8 lbs per acre to 1050·5 lbs per acre in 100 days, when molasses is added to such a system.

The above observations explain why phosphates have been found to be specially beneficial for crop production all over the world, because phosphates when mixed with organic substances like farmyard manure, straw, leaves and other plant residues can act as partial substitutes for nitrogenous fertilizers by fixing atmospheric nitrogen, supply available phosphrous and potash and trace elements and build up soil fertility by increasing humus status.

SUMMARY

1. From the analysis of Indian rock phosphates it appears that they are very much worth for the manufacture of super-phosphates, as compared to other phosphate rocks.

2. When mixed with soils they enhance the fixation of nitrogen in presence of decomposing organic matter.

3. The available phosphate increases when the phosphate rocks are added to the soil along with decomposing organic matter.

4. The exchangeable calcium increases with lapse of time when phosphate rocks are added to the soil in presence of decomposing organic matter.

5. In short phosphate rocks when mixed with organic substances, act as partial substitutes for nitrogenous fertilizers by fixing atmospheric nitrogen, supply available phosphorus and potash and trace elements and build up soil fertility by increasing the humus status.

REFERENCES

1. Dhar, N.R., (1934). *Nature*, 134., (1934) *Proc. Nat, Acad Sci. India.*, **4**, 572.; (1935) *Presidential Address Nat. Acad. Sci. India.* (1937) *Presidential Address Nat. Acad. Sci., India,* (1953), *Presidential Address, Nat. Acad. Sci. India.*
2. Lang. A. L.,(1952) *Farm, Quarterly.*
3. Dhar, N. R., (1954) *Kungl. Lant. Analer.*, **21**, 50-80.
4. Robinson, Mclean and Williams, (1935), *J. Agric. Sci.* **19**, 315.
5. Treadwell, E. F. and Williams, (1930). *Analytical Chemistry*, Vol II.
6. Dyer B., (1894). *Trans. Chem. Soc.*, **65**, pp. 115-116.
7. Pembrton., (1930). "*Methods of Analysis*" A. O. A. C.
8. Piper, C. S., (1947). "*Soil and Plant Analysis*," pp. 184-85.
9. Dhar, N. R., (1953)- *Presidential Address, Nat. Acad. Sci., India.*
10. Collings, H. G., (1947). *Commercial Fertilizers*, 5th Edition.

AMMONIUM PHOSPHATE AS A FERTILIZER IN THE GROWTH OF PLANTS IN SAGAR SOIL

By

P. N. AWASTHI *and* A. K. BHATTACHARYA

Department of Chemistry, Sagar University

(Received on 11th November, 1954)

Nitrogen as is well-known, is the most important nutrient of the plant kingdom and in an essential constituent of the fundamental living matter, the protoplasm. That the majority of Indian soils are poor in nitrogen has been emphasised from time to time by various workers working on Indian soils. J. A. Voelekar[1] in the "Improvement of Indian Agriculture" reports "On looking into the analysis of Indian soils, which have been recorded and others which I have made myself, I find that with the exception of the black cotton soils, Indian soils are generally deficient both in organic matter and nitrogen." The Royal Commission on Agriculture in India[2] also states " of the principal plant food materials in which the soils of India are deficient, by far, the most important is nitrogen and the manurial problem in India, is in the main one of nitrogen deficiency."

Experiments with Indian soils point out yet another very important factor for the poverty of Indian soils. This is its defficiency in humus content. The Agricultural Chemist to the Government of U. P. in one of his recent publications has stated the following :—

"In brief utilising as much organic matter as is available and supplementing this with inorganic fertilizers holds the best promise for solving our food problem."

Another important experimental observation made by a band of workers in soil science is the process of denitrification in virgin soils as well as in soils mixed with fertilizers. The process of denitrification has been explained by different workers from different points of view but all of them come to one and the same conclusion that the artificial manures lose much of their nitrogen in free state back to the atmosphere. Experimental records show that attempts have been made by the soil chemist to minimise this loss of nitrogen due to denitrification process. It has been observed by several workers that addition of organic matter with inorganic fertilizer decreases the denitrification process. In addition, the presence of organic matter in the soil improves the physical texture and colloidal properties of the soil. It also enriches the soil in its humus content and trace element. The high absorptive capacity of humus imparts the special physical properties to the soil to retain ammonium, potassium, calcuim, magnesium and other ions and liberate them slowly according to need of the plant.

The physical and chemical characters of soils vary from place to place and are dependent on the climatic conditions and the temperature of the place. Thus it is not possible for any one or even a band of workers to find out the most suitable composition of artificial fertilizer and energy rich material which would

be efficient for Indian soils in general. It is, therefore, very necessary that a thorough analysis and assay of the soil of a particular place must be first made, followed by experiments on nitrogen fixation and control on denitrification process in presence of inorganic fertilizers and organic matter. The results of these experiments only will enable one to recommend the use of a particular composition of inorganic fertilizer and organic matter to the farmer of that locality.

We have therefore taken up the sytematic study of ammonium phosphate as inorganic fertilizer in the growth of plants in Sagar soil. A thorough survey of neighbouring soils were made and twelve samples from different places were collected. These soils were collected from the fields under cultivation. These soil samples were completely, analysed both from physical and chemical points of view. The soil samples were found to be almost similar and therefore one of the soil was taken for further study due to its easy availibility and nearness to the chemical laboratory.

A study of the decomposition of ammonium phosphate in the presence of the above soil was first made and the results, were published a few months back in the University Journal.[3] A brief reference of the work is given below:—

Ammonium phosphate was taken and mixed with the soil in the ratio of 1 gm, 3 gms, per pound of the soil. These sets were exposed to sunlight daily for eight hours and the daily temperature was recorded. The average temperature was 40°C. 50 ml of water per pound of the soil was mixed and this moisture was maintained constant throughout the length of the experiment.

With samples containing 3 and 5 gms of ammonium phosphate per pound of the soil the loss in nitrogen[4] was found to be 67·5-58% in two months time.

Shutt[5] in Canada and Lipman, Blair[6] and others reported a similar loss. This loss was explained by Russell[7] as due to the leaching and Lohnis[8] as due to bacterial action. The authors of the present paper explained it from the point of view of oxidation and nitrification of ammonium phosphate by photo-chemical process which is in complete harmony with the observations of Dhar[9] and co-workers.[10] The continuous loss of nitrogen on exposure to sunlight at an average temperature of 40°C was estimated thus : When ammonium phosphate is added to the soil the first product formed is ammonia from proteins which in its turn is oxidized to nitrites and nitrates. Now since the whole of ammonia cannot be converted readily into oxidized products, the ammonium ions and sometimes free ammonia have got ample chance to exist side by side with nitrite ions or nitrous acid, nitrate ions or nitric acid or both and thus the decomposition takes place with the evolution of nitrogen gas as a result of the formation and decomposition of unstable ammonium nitrite.

In order to reduce this loss of nitrogen, experiments were made by mixing the powdered wheat straw to a mixture of soil and ammonium phosphate. 3 mgs of wheat straw per pound of the soil was taken with 50 ml of water and was mixed with soil containing 3 gms per pound of ammonium phosphate. The sample was in duplicate in glass jars and these were exposed daily for 8 hours in sunlight. On analysing the samples after two months the loss in nitrogen was found to be 26·99% while a loss of 67·5-68% of nitrogen was observed in two months time without the addition of wheat straw to a sample of soil and ammonium phosphate.

RESULTS

TABLE No. I

Exposed Set

3 gms of ammonium phosphate, with 50 ml of distilled water was mixed per pound of the soil and this moisture was maintained constant throughout the length of the experiment.

Date of analysis	Total N	Total C	% loss
3-3-53	·1414%	·4000%	...
10-3-53	·1106%	·3870%	21·8%
18-3-53	·0820%	·3866%	42·0%
3-4-53	·0600%	·3850%	57·6%
3-5-53	·0460%	·3840%	67·5%

TABLE No. II

Exposed Set

3 gms of ammonium phosphate, 3 gms of powdered wheat straw, with 50 ml of distilled water mixed per pound of the soil and this moisture was maintained constant throughout the length of the experiment.

Date of analysis	Total N	Total C	% loss
3-3-54	·1456%	·5008%	...
18-3-54	·1367%	·4758%	6·11%
3-4-54	·1261%	·4508%	13·32%
3-5-54	·1063%	·4008%	26·99%

Analysis of Wheat straw

Total carbon	39·04%
Total nitrogen	0·6363%
C : N ratio	61·35%
Moisture	4·300%
Loss on ignition	91·35%
Ash	8·65%
SiO_2	7·00%
CaO	0·2882%
MgO	0·0964%
K_2O	0·7015%
P_2O_5	0·0620%

It was thus seen that the loss of nitrogen on the addition of wheat straw to a mixture of ammonium phosphate and soil in presence of light is about 2/5th of the loss of nitrogen with soil and ammonium phosphate alone. It appears that when wheat straw is added to a mixture of soil and ammonium phosphate, it acts as a conservator and slows down the loss of nitrogen probably, because a part of ammoniunm nitrite formed is likely to be converted into ammonium sulphate or chloride and alkali nitrates which are more stable.

Similar results have been obtained by Dhar[11] and co-workers who concluded in 1935 from their experiments that a mixture of ammonium sulphate and organic matter is a better fertilizer than ammonium sulphate alone. Collings[12] in U.S.A. has got similar results he states :—

"Many agricultural experiment stations have shown that the incorporation of green manures in the soil, in addition to a complete fertilizer, results in an increase in the yields of succeeding crops. Most soils are benefitted by the addition of suitable organic matter regardless of the quantity they contain. Johnson, (1924) at the Virginia Truck Experiment Station found that when one ton of a 6-4-8 fertilizer was applied, the average yield of potatoes was 155 bushels, but when a green manure crop was turned under previous to the addition of the fertilizer, the average yeild was raised to 232 bushels." Again on page[13] it has been stated. "When virgin soil is put under cultivation, a rapid decay and nitrification of organic matter is induced, and the resulting carbon and nitric acids materially aid in making available the insoluble phosphates of the soil. As supply of organic matter decreases so do the quantities of carbonic and nitric acid and in turn the quantity of available phosphoric acid. This natural process has played an improtant role in decreasing the demand for super-phospates as for the potashes in the older populated areas."

A similar report was made by F. E. Bear[14] : —

"When crop residues were returned to the soil, the yield increases in terms of total produce of snap beams and carrots averaged 12%. A rye cover crop added $7\frac{1}{2}$%, and $2\frac{1}{2}$ tons of cornstalks another 14%. Thus for organic matter additions totalling little more than 5 tons an acre a year the yield increase was $33\frac{1}{2}$%.

"The best organic matter system under continuous culture raised crop yields to 39%. This involved crop residues cover crops and soya beans for mulching every second year. The best 5 crop rotation programmes raised average yields more than 60%. These involved letting the land grow up to weeds, using winter grains and deep-rooted legumes, growing sweet corns and soya beans or employing similar procedure two years out of every four."

We have also investigated the effect of wheat straw and ammonium phosphate on the growth of Indian *bhindi* plant. *Bhindi* plant was grown in pots. Each of which contained 44 lbs of the soil. In pot No. 2, 3 gms of ammonium phosphate and 50 ml of water per pound of the soil was added. In pot No. 1, 3 gms of ammonium phosphate, 3 gms of powdered wheat straw and 50 ml of water pound of the soil were taken, while in the pot No. 3, soil was mixed with water at 50 ml per pound. In these pots *bhindi* seeds of the same variety were sowed. Eight seeds per pot were sown such that they were at equal distance from each other being situated at the circumference of the circle. After 15 days 4 plants which were nearly similar were maintained while the other four each pot were taken out carefully. The date of seedling, flowering leafing and fruiting were recorded. The pots were exposed daily for 10 hours and moisture was maintained constant.

TABLE No III

Observations made after 2 months, *i.e.*, on July 22, 1954

	Sample No. 1	Sample No. 2	Sample No. 3
Height of plant	3′–9″	3′- 1″	2′–11″
Diameter of stem	1·6″	1·2″	1·6″
Green wt. of plant	102·9 gms	76·07 gms	77·66 gms
Dry weight of plant	19·3 gms	14·93 gms	16·9 gms
No. of leaf	8	9	15
Shape of leaf	Normal	Normal	Sharp cut in leaves
Colour of leaf	Dark green	Light green	Dark green
Length of branch at 8th node	6″	7·4″	9″
Area of branch	1·50″	0·84″	0·7″
No. of buds	6	4	6
No. of fruits	...	1	.
Weight of fruits	...	5·61 gms	...
Length of fruits	...	3·2″	...

TABLE No. IV

Observations made on 3rd of September, 1954

Observations	Sample No. I	Sample No. II	Sample No. III
Height of plant	5′–6″	4′–1″	4 ft.
Diameter of the stem	2·6″	1·25″	1·65″
Green weight of the plant	290 gms	72 gms	85 gms
Dry weight of the plant	90 gms	25 gms	34·75
Number of leaves	10	1	5
Shape of the leaves	Normal	Normal	Sharp cutted
Colour of the leaves	Dark green	Light green	Dark green with brown spots
Length of the branch at the 8th node	9″	3·5″	4·8″
Area of the branch	1·3″	6·45″	0·55″
Number of buds	...	...	...
No. of fruits	Seven all green	Four 3 dry and one green	Five 4 dry and one green
Length of the fruits	5·5″, 6″, 5·1″, 5·2″, 5·5″, 5·5″, 3·8″	3″, 5·6″, 5·5″, 4·8″	5″, 4·9″, 6″, 6·2″, 6″
Weight of the fruits	110 gms	28 gms	35 gms

Comparing the above two tables we find that the growth of Indian *bhindi* in the sample I, which contained a mixture of equal amounts of ammonium phosphate and straw is better than either the soil as such or soil with ammonium phosphate, which is in full agreement with the theoretical results.

Similar results have been obtained at Rothamsted[15] Experimental Station which show clearly that both straw and cowdung when added to artificial fertilizer produce beneficial results.

	Yield of potatoes in tons/acre	
	Non, nok	N, Nok
No farmyard manure	4·0	4·4
With farmyard manure	9·3	11·1
Response to farmyard manure	5·3	6·7

It is evident from the above table that the yield of potatoes should have been 9·7 tons (9·3 tons due to farmyard manure and 0·4 tons due to artificial nitrogen), but the total yield is 11·1 tons. These results show that the addition of farmyard manure to artificial nitrogen produces an enhanced effect of the added mineral nitrogen.

Moreover, the following experiments on potatoes, carried out at Rothamsted[16] for a number of years in which a given dressing of straw and nitrogen was ploughed into the soil, are compared with the same quantity of straw rotted with the same quantity of nitrogen in a compost heap and then applied to the field. The former had always a better yield than the latter yield than the latter as shown below :—

21 years (1934–45)

	Year of applying straw		Year after application	
	Compost	Straw-ploughed in	Compost	Straw plough
Potatoes (tons per acre)	7·86	9·40	7.40	7·97
Sugar beet, Sugar (cwt per acre)	37·00	41·20	36·40	38·20
Barley, gram (cwt per acre)	27·70	31·20	26·50	27·90

The above experimental results at Rothamsted and of Sheila Dhar Institute bear a strong support to our conclusion that a mixture of ammonium phosphate and straw is a better fertilizer than ammonium phosphate alone.

In explaining the photo-synthesis in plants, Dhar[17] postulated in 1933 that the important photo-chemical reaction was the decomposition of matter by absorption of light according to the equation :—

$$H_2O + 112 \text{ Cal} = H + OH$$

In recent years this view of the mechanism of photo-synthesis has been supported by the use of carbonic acid containing isotopic carbon. In explaining the nitrogen fixation the best mechanism seems to be the same, *i.e.*, the decomposition of water into $H + OH$ by absorption of energy got from the oxidation of wheat straw.

It is well-known that in symbiotic or non-symbiotic nitrogen fixation there is hardly any increase of nitrogen in presence of small amounts of ammonium salts. Similarly in our experiments a fall in nitrogen is observed on the addition of ammonium phosphate alone. This is due to the escape of free nitrogen evolved as a result of formation and decomposition of unstable ammoninm nitrite. It has been shown that the wheat straw acts as a conservator and retards the loss of nitrogen. In other words the wheat straw acts as a inbibitor in nitrification. This result has also been confirmed by the results on *bhindi* plant.

REFERENCES

1. Voelcker, J. A., *Improvement of Indian Agriculture*, 1893, p. 37.
2. Report of the Royal Commission on Agriculture in India, (1928), pp. 80—93.
3. Awasthi P. N., Bhattaeharya, A. K., *Sagar University Journal*, 1953-54, p. 41.
4. Awasthi P. N., Bhattacharya, A. K., *Sagar University Journal*, 1953-54, p. 43.
5. Shutt, F. E., *J. Agri. Sci.*, 1910, **3**, 335.
6. Lipman and Blair, *Soil Sci.*, 1931, **1**, 12.
7. Russell, E. J., *Soil Conditions and Plant Growth*, 1950 Ed., p. 300.
8. Meiklejohn, J., *Ann. Appl. Boil*, 1940, 272, 558.
9. Dhar and Gopal Rao, *Soil Sci.*, 1931, **31**, 379.
10. Dhar, Bhattacharya and Biswas, *J. Ind. Chem. Soc.: Val. X, Issue 12.*
11. Dhar, N. R. and Mukerjee, S. K., *J. I. C. S.*, 1936, **8**, 159--175.
12. Collings, G. H., *Commercial Fertilizers*, 1947, p. 390
13. Collings, G. H., *Commercial Fertilizers*, 1947, p. 213.
14. Bear, F. E., *J. I. C. S.*, May, 1953.
15. Journal of Indian Chemical Society, *Vol. XXX*, May, 1955, No. 5.
16. Russell, E. J., *Soil Conditions and Plant Growth*, 1950 Ed.
17. Dhar, N. R., Presidential Address to the Academy of Sciences, India, 1936.